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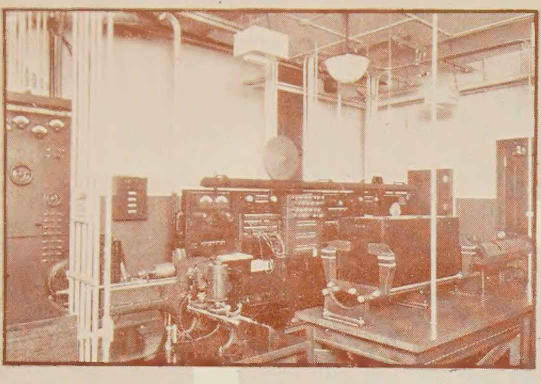
WINTER CONVENTION, NEW YORK, JAN. 28-FEB. 1

Places to be Visited During the A. I. E. E. Winter Convention



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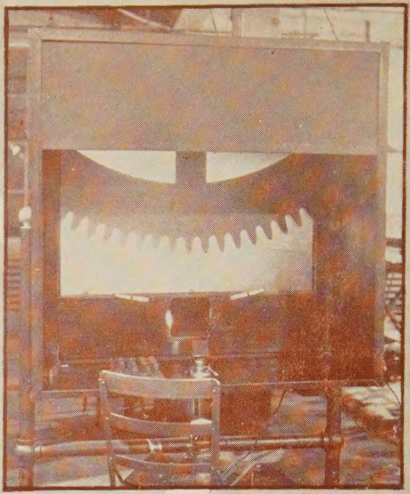

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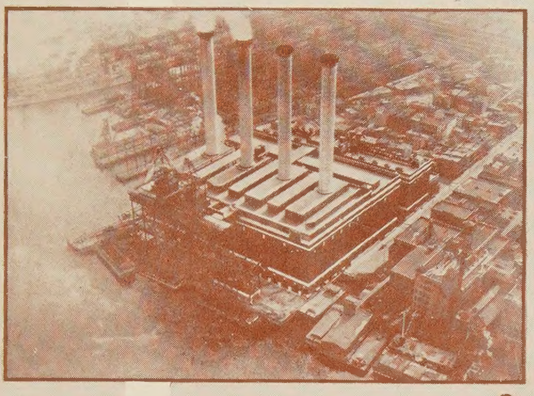

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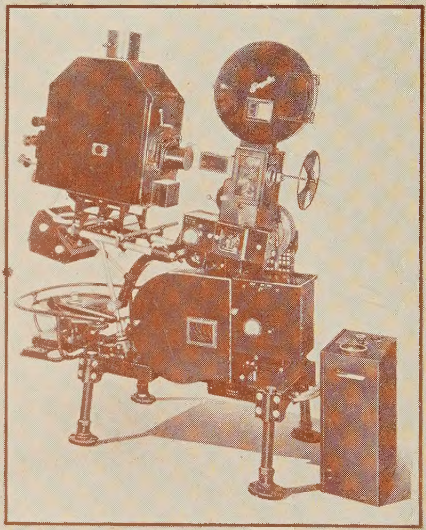

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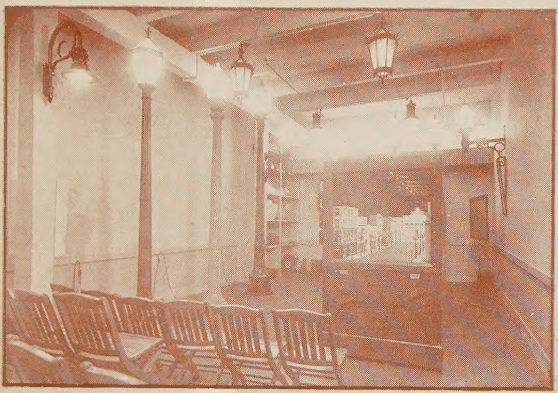

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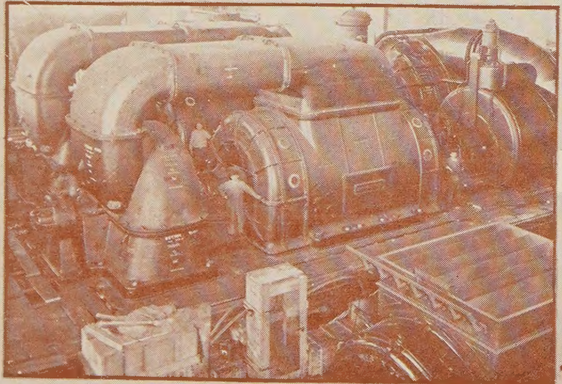

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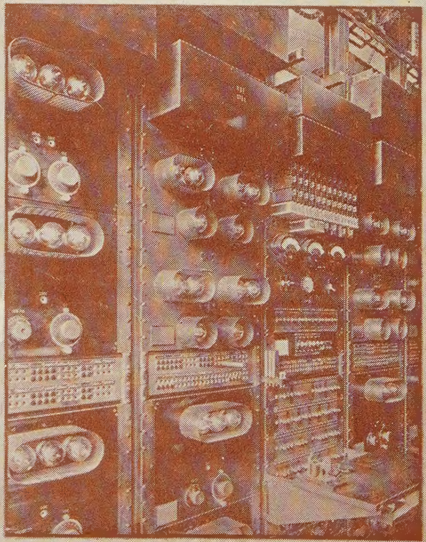

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JOURNAL

OF THE

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George R. Metcalfe, *Editor*

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(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

MEETINGS

of the

American Institute of Electrical Engineers

WINTER CONVENTION, New York, N. Y., January 28-February 1, 1929

REGIONAL MEETING, Middle Eastern District No. 2, Cincinnati, Ohio, March 20-22, 1929

REGIONAL MEETING, South West District No. 7, Dallas, Texas, May 7-9, 1929

SUMMER CONVENTION, Swampscott, Mass., June 24-28, 1929

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The American Society of Civil Engineers, Annual Meeting, Engineering Societies Building, New York, N. Y., January 16-18, 1929

The American Institute of Mining and Metallurgical Engineers, Annual Meeting, Engineering Societies Building, New York, N. Y., February 18-21, 1929

JOURNAL OF THE A. I. E. E.

DEVOTED TO THE ADVANCEMENT OF THE THEORY AND PRACTISE OF ELECTRICAL ENGINEERING AND THE ALLIED ARTS AND SCIENCES

The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Vol. XLVIII JANUARY, 1929 Number 1

IS Your Section a Success?

We can hardly expect to find complete unanimity as to what constitutes success but all will agree that a section which keeps high the enthusiasm of its members is well on its way to winning the laurel crown.

What activities provide the fuel that feeds the fires of enthusiasm? Some of them were well set forth by Mr. Potter, Chairman of the St. Louis Section, and reported on page 927 of the December JOURNAL. He puts his finger on the MAJOR OPPORTUNITY—THE DEVELOPMENT OF THE INDIVIDUAL ENGINEER. A man of forty is ordinarily a more valuable member of society than a youth of twenty because he has had the benefit of growth based on experience and contact with his associates. Section activities offer particularly rich opportunities for growth but they come mainly through personal performance, such as carrying program or committee responsibilities. It is the consciousness of the resulting growth, of the spreading horizon and clearer vision, that stirs the enthusiasm.

A study of the programs of the sections seems to indicate that only few reflect a recognition of the opportunity referred to. As a means for providing lecture platforms and forums for technical or more popular subjects, many of the sections could not be improved upon, and often the attendance shows that a popular chord has been struck. Lecture or demonstration meetings have a very definite and valuable place in section activities. They are informative, they help to interpret engineering work to the public and they keep some members interested who otherwise might not be. However, in terms of the larger possibilities they only scratch the surface and in so far as the programs bring only a small executive committee into action, the personal activity benefit is very limited.

Experience teaches that that executive committee is serving best which does no more than decide on policies and that delegates practically all activities to well chosen committees thereby giving the latent talents of the younger members particularly an opportunity for play. Such committees could include some or all of the following: program, membership, reception, finance, graduates follow-up, publicity, discussion, prizes, cooperation with Branches, attendance, civic reports or problems.

The general plan should be mapped out so these committees will have something to do and so that "something" will offer a maximum of personal contacts and opportunities for personal development. This does not require any strain on the imagination. The size of the section and other local conditions will determine the best committee plan.

Participation in such activities helps the engineer to fit himself for larger opportunities, for national committee service, for greater usefulness in civic organizations, as well as for more effective service in his daily work. He will be an enthusiastic engineer and citizen.

A section made up of enthusiastic members is a successful section.

An organization made up of successful sections is a power that brings credit and helpfulness to the entire profession.

R. F. Schuchardt

President.

The Institute Publications. What Changes Should be Made?

The question as to what can be done to improve still further the Institute publications was discussed at length during the recent meeting of the Publication Committee. The policy in effect since January, 1928, of publishing the TRANSACTIONS quarterly and printing papers in abridged form in the JOURNAL, with complete copies available upon request of those desiring more detailed information, has solved many of the physical problems of the committee. As a further development of the committee's work it is now proposed to consider means of making the contents of the publications more valuable to the membership. It is felt, for example, that the JOURNAL would be more widely read and referred to if in addition to the present contents, special features were added in the hope that they would be of general interest to the entire membership.

Some of the suggestions already under consideration by the committee are:

(a) That a section in the monthly JOURNAL be devoted to a review of progress in the art of electrical engineering. Under this or possibly a more appropriate heading could be included short articles on achievements in engineering and related fields. Some of the articles might be abstracts from other publications, and others might be important news items of interest to electrical engineers. Such a digest could give a fairly good perspective of the general progress in engineering and would stimulate interest, broaden the usefulness of the JOURNAL, and increase the number of readers.

(b) That space be allotted in the JOURNAL for correspondence. This would afford an opportunity to present brief discussions on topics of interest. Under this heading short comments on Institute activities could properly be included, such as the work of the various technical committees, the Institute Standards, Section and Branch work, and many other matters of special interest to the membership.

(c) Publication of an article each month on a timely subject by some prominent scientist would be a splendid addition to our JOURNAL if it could be accomplished.

(d) A question-and-answer department might be established in which Institute members could submit questions of interest to electrical engineers, and answers could be solicited from other members for publication in a later issue.

The features briefly mentioned are merely illustrations of some of the ways in which the Institute Publications can be made more valuable, and no doubt there are other plans that will accomplish the same purpose. An invitation is therefore extended to all the members to forward to Institute headquarters, New York, not only comments and criticisms on the suggestions presented here, but also to submit in a specific and concrete form any other recommendations they may have to offer. The members should avail themselves of this opportunity to express their opinions as to the manner in which this most important activity of the Institute will more fully meet their needs.

It should be understood that substantial improvements cannot be made without corresponding increase in expense, and therefore could not be put into effect until after the committee had made its definite recommendations to the Board of Directors with an estimate of the cost, followed by approval of the Directors accompanied by favorable action upon the necessary appropriation. It is hoped by the committee that a sufficient number of replies containing specific suggestions will be received by February 1 to warrant the preparation of a preliminary report to the Board of Directors.

PUBLICATION COMMITTEE,
W. S. GORSUCH,
Chairman

Carrying Peak Loads

On most utility systems the costs of carrying the peak load are high, and many methods have been suggested to reduce them. The best method is to study load distribution and sell energy under conditions that reduce the peak load, but there is a limit to this method that is soon reached on many properties. Then it becomes necessary to study peak loads from the point of view of maximum system economy in power generation.

At the recent A. S. M. E. convention in New York Prof. A. G. Christie discussed the peak-load problem and indicated many economic and operating advantages in favor of the use of the steam accumulator. These held especially well for systems with modern stations and large peak loads of short duration. Essential system savings are made by having low fixed charges on peak-load facilities and low total costs on base-load plants. A combination of peak-load and base-load stations gives the minimum system power-production costs.

It is unsafe to generalize on the use of the steam accumulator as the cheapest and best peak-load-carrying device. Systems are different and have variations in service standards, in generating-plant reserve and in station first costs and operating costs. But just because the idea of using a steam accumulator is new is no reason for rejecting it for peak-load operation. Even the Diesel engine with its high first cost has been advocated as a peak-load-carrying agency on some systems. The logical procedure is to make a study of each property concerning the utilization of all methods and devices to reduce power costs and then to use the one that offers the most possibilities.—*Electrical World.*

Abridgment of

Ionization Studies in Paper Insulated Cables—II

BY C. L. DAWES*, H. H. REICHARD† and P. H. HUMPHRIES‡

Member, A. I. E. E. Associate, A. I. E. E. Associate, A. I. E. E.

***Synopsis.**—The power dissipated as ionization loss in impregnated-paper-insulated cables is much more harmful than the power dissipated in the solid dielectric. The paper presents methods of separating this ionization loss from the total dielectric loss. This separation is based on the assumption that the power loss in the solid dielectric varies as the square of the voltage, even above ionization. To verify this assumption, samples of wood-pulp paper, impregnated with three different cable compounds under such conditions as to remove nearly all traces of occluded gases, were made up. These tests showed that up to 300 volts per mil, and at room temperature, the power factor and capacitance are substantially constant, and that the power loss varies as the square of the voltage.*

Measurements of the electrical properties of ionized air films showed that above the ionization voltage the power loss is a linear function of the voltage. Power curves of cables can thus be analyzed into two components; one giving the loss in the solid dielectric and one giving the loss in the ionized air films. This analysis is verified with glass cable models. The power-factor curve and the energy current of the cable can each be analyzed into three simple components and extrapolated if desired. The character of the capacitance curve, which varies in different cables, is determined by the positions and thicknesses of the gas films.

PROCEDURE

THE dielectric-loss measurements which are given in this paper were made on a bridge, the principle of which was given in Part I of the paper.[1] This bridge will be described shortly in a paper§ before the Institute. The dielectric medium of paper-insulated cables consists of impregnated paper, the impregnating material, and thin gas films which may be air or gases from the impregnating material all in series. In this article, the insulating paper and the impregnating material will be referred to as the solid dielectric and the air and vapors as gases.

The variation of the dielectric characteristics of the solid material with voltage is quite different from the variation of the dielectric characteristics of the gaseous films with voltage. This fact provides a means of separating each of these two losses from the total loss in a cable. This is important, for, as is well known, the energy which is dissipated in the gas films is very insidious and destructive in its effects on the dielectric; hence it is much more harmful to the life of the cable than the energy dissipated in the solid material.

DIELECTRIC CHARACTERISTICS OF THE SOLID MATERIAL

The separation of the losses within the cable dielectric can be accomplished only when the dielectric characteristics of cable paper, impregnated under conditions that remove essentially all occluded gases, are known.[2,3] Samples for this purpose were made up consisting of 12 circular sheets of impregnated paper. These were tested between flat circular electrodes, of 11.9-in. (28.4-cm.) diameter. Special apparatus was constructed permitting both the paper and compounds to be dried and treated by vacuum and temperature separately, and the sample to be prepared without occluding gases.

Three different compounds were chosen for impregnating the paper and producing test samples. These compounds were supplied by three different cable manufacturers. The first compound is a light oil, specially prepared so that amorphous constituents are removed, and is designated as compound *A*; the second is a paraffin-base cylinder-oil compound of medium viscosity at room temperature; the third is of a petrolatum base, containing a small percentage of rosin, and has considerable viscosity at room temperature.

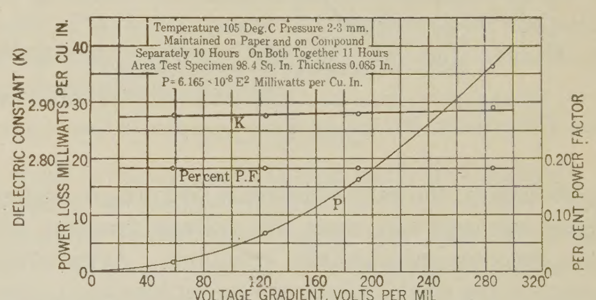

FIG. 1—CHARACTERISTICS OF WOODPULP PAPER IMPREGNATED WITH COMPOUND A, FREQUENCY 60 CYCLES, TEMPERATURE 19.5 DEG CENT.

Tests were made over a considerable range of frequencies and temperatures, but for the purpose of this paper, the results obtained at room temperature and at a frequency of 60 cycles per second only are necessary. The power factor, the dielectric loss in milliwatts per cu. in. and the dielectric constant of Compound *A* as functions of voltage gradient are given in Fig.1. Similar characteristics were obtained for the other two compounds. In Fig. 1 there is no indication of an ionization voltage. The power factor remains essentially constant at all voltages. There is a very slight increase in capacitance which, up to 300 volts per mil, is less than 1 per cent. These same conditions were found to hold with the other two samples. Hence it

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‡Instr. in Elec. Engg., The Harvard Engg. School.

1. For numbered references see Bibliography.

§*Some Problems in Dielectric-Loss Measurements*, by C. L. Dawes, P. L. Hoover, and H. H. Reichard.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

appears very probable that with the most careful impregnation, removing nearly all traces of occluded air, at gradients up to 300 volts per mil and at room temperature, the power factor and capacitance of impregnated paper are essentially constant; the power loss varies as the voltage squared.

Dielectric Characteristics of Gas Films

Considerable investigation of the electrical properties of air films has been conducted independent of cable research. The air film is tested under conditions of "restricted ionization," the current flow being limited by a slab of Pyrex glass. In Fig. 2 are given the following characteristics of a 0.3745-mm. (14.75-mil) air film as a function of current: the voltage gradient, and the power loss and the capacitance per cu. cm. These characteristics show that the voltage gradient below ionization is proportional to the current. After ionization has begun, the rate of increase of voltage gradient becomes less and less until the voltage gradient ultimately becomes substantially constant. After ionization begins, the relation between power loss and current and between capacitance and current are nearly linear.

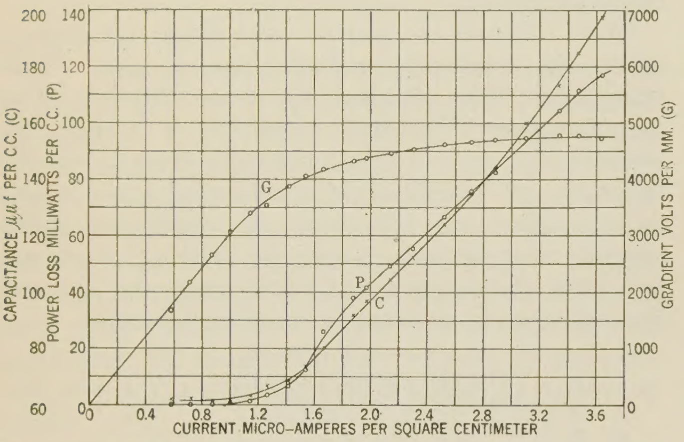

Fig. 2—Characteristics of 14.75 Mil (0.3745 Mm.) Air Film, Frequency 60 Cycles, Temperature 19 Deg. Cent

Power Characteristics of Gas Films Distributed in Cable Dielectric

Within the cable dielectric, the gas films are distributed indiscriminately throughout the insulation. Each of these gas films will become ionized as soon as its voltage gradient exceeds a certain critical value. The power loss characteristic of each film then becomes linear, similar to the characteristic shown in Fig. 2. Consider, five concentric gas films, a, b, c, d, and e, distributed radially outwards through the insulation, gas film a being adjacent to the copper and e adjacent to the sheath. Assume that the voltage on the cable is being raised, and that the change in capacitance of the cable is so small that the current is practically proportional to voltage. Below the ionization voltage, the loss in the gas films is zero. When the voltage gradient across a reaches its critical value at E_1, (Fig. 3), the power loss in this film will be linear with further increase in voltage, as shown by the straight line a. As the voltage is further raised, film b becomes ionized at voltage E_2 and the relation of its power loss to voltage is given by the straight line b. In a similar manner, films c, d, and e ionize at voltages E_3, E_4, and E_5 and their power characteristics are given by lines c, d, and e.

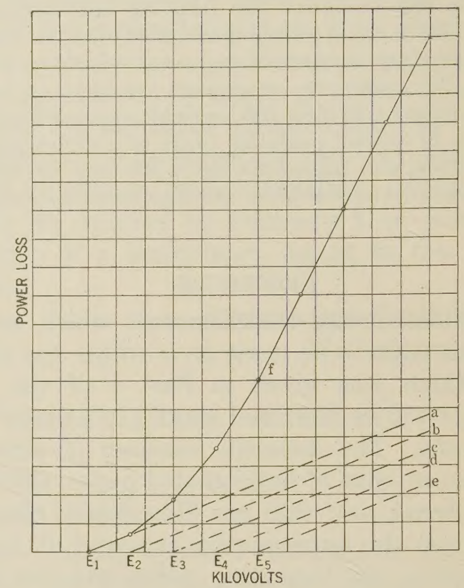

Fig. 3—Power Loss in Cable Dielectric Due to Successive Gas Films

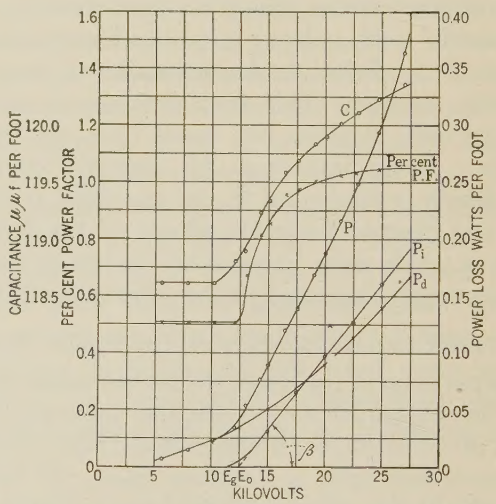

Fig. 4—Characteristic Curves of Cable No. 12

500,000 = cir. mil., single-conductor 16/64-in. paper cable with copper shielding tape 10-ft. length, frequency 60.6 cycles, temperature = 20 deg. cent.

The total loss at any voltage is found by adding the ordinates of the curves.

In the actual cable, where the air films are very thin, the power curve up to voltage E_5 will be concave upwards. Above voltage E_5 (point f on curve) the air films have all become ionized and the power curve becomes linear.

Analysis of Cable Power Curve

Fig. 4 shows the three well-known characteristic

curves of a 10-ft. length of 500,000-cir. mils, 16/64-in. paper, 8/64-in. lead, single-conductor cable with copper shielding tape. The power curve P, the power-factor curve and the capacitance are plotted against kilovolts. An examination of these curves shows that this cable has some ionization.

In Fig. 5 this same power curve P ($a\ b\ d$) is plotted on logarithmic paper. Up to 12.5 kv., the ionization voltage, this logarithmic power characteristic is a straight line having a slope of 2.0. This shows that below the ionization voltage the power loss varies as the square of the voltage. This loss must all occur in the solid dielectric, so that this portion of the curve confirms the results obtained with the compounds and given in Fig. 1. A discontinuity occurs at point b, the ionization voltage, and the characteristic from $b\ e\ d$ now becomes a broken line. If it be assumed that above the ionization voltage the power loss in the solid dielectric still continues to vary as the square of the voltage, the loss in the solid dielectric will with little error be given by the line $b\ c$ where $b\ c$ is the continuation of line $a\ b$.

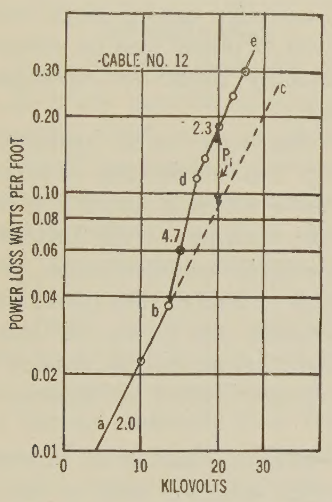

FIG. 5—LOGARITHMIC PLOT FOR FIG. 4

The difference between the curves $a\ b\ e\ d$ and $a\ b\ c$ must be the power loss in the ionized gas films. This difference is transferred and plotted in Fig. 4 as the curve P_i. It is a linear curve and its equation is of the form

$$P_i = K_1 (E - E_0) \quad (1)$$

where K_1 is the slope of the line (= tan β, Fig. 4), E the voltage, and E_0 the intercept of the line with the voltage or X-axis. $K_1 E_0$ is the intercept of the line, when extended, with the power or Y-axis. Likewise, the dielectric power curve P_d is plotted in Fig. 4. Its equation is of the form

$$P_d = K E^2 \quad (2)$$

The equation for the total power-loss curve P

$$P = K E^2 + K_1 (E - E_0) \quad (3)$$

It is to be noted in Fig. 4 that the ionization curve P_i, obtained analytically, is identical in character with the curve of Fig. 3, obtained synthetically. The power curves of a large number of cables have been similarly analyzed and the same relationships have been obtained in every case. In Table I are given the constants of Cable 12, and of three other cables having varying degrees of ionization.

TABLE I

Cable	14	12	B	A
K	1.21×10^{-10}	2.24×10^{-10}	1.67×10^{-10}	1.62×10^{-10}
K_1	2.38×10^{-6}	1.28×10^{-5}	3.81×10^{-5}	8.8×10^{-5}
E_0	17,500	12,500	24,000	18,000
E_g	17,500	11,500	24,000	14,000
$K_1\ E_0$	4.05×10^{-2}	16.0×10^{-2}	0.953	15.8×10^{-2}

E_g = Ionization voltage.

This tabulation shows that the cables with highest ionization loss have the largest values of the ionization constant K_1, which is the slope of the ionization curve. (See Fig. 4.) Cable A, whose value of K_1 is 6.9 times that for Cable 12, has a much smaller dielectric-loss constant K.

In the opinion of the authors, the constants K, K_1 and E_g are criteria for cable quality. The foregoing analysis gives a simple method for the determination of the power dissipated in cables for voltages far in excess of values determined experimentally. It is merely necessary to extrapolate two straight lines, the line $a\ b\ c$, Fig. 5, to obtain the power loss in the solid dielectric and the straight line P_i, Fig. 4, to obtain the power dissipated in ionization.

CABLE MODELS

In order to verify the foregoing method of analysis, it was deemed advisable to apply them to cable models composed of Pyrex glass tubing and intervening air spaces. With such models, it is possible to determine the dielectric properties of the glass alone, which leaves only one unknown quantity,—the dielectric properties of the gas film. Data taken with two such models, one having a single concentric air space and another having three such air spaces in series verified in every particular the results obtained with actual cables. In each case the ionization power-loss curve becomes linear, after complete ionization has been been attained.

POWER-FACTOR CURVE

It follows from the equation (3) that the power factor

$$\text{P. F.} = \frac{K E^2 + K_1 (E - E_0)}{E^2 C \omega} \quad (4)$$

where ω is 2π times the frequency.

Since the variation of capacitance C with voltage is small, equation (4) gives a means of extrapolating the power-factor curve without actually carrying the cable to the high stresses that would be necessary to determine the curve experimentally.

If equation (4) be differentiated with respect to voltage, it can be shown that if the term $E \dfrac{d\,C}{d\,E}$ is small compared with $2\,C$, the point of maximum power factor occurs when $E = 2\,E_0$. This condition is closely approximated in Cable 12, Fig. 4.

Equation (4) may be divided into three terms.

$$\text{P. F.} = \frac{K}{C\,\omega} + \frac{K_1}{E\,C\,\omega} - \frac{K_1\,E_0}{E^2\,C\,\omega} \tag{5}$$

Each of these terms represents a simple curve. These component curves are plotted in Fig. 6, which also shows the resultant power-factor curve extrapolated far beyond the data obtained experimentally.

Current Curve

The energy current

$$I = \frac{P}{E} = \frac{K\,E}{C} + K_1 - K_1 \frac{E_0}{E} \tag{6}$$

Neglecting change in capacitance, the first term is

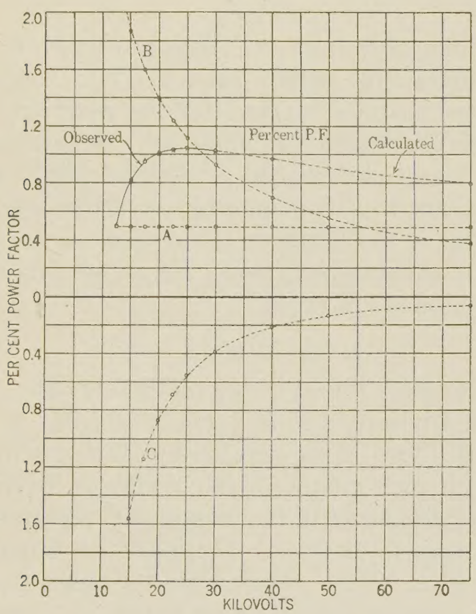

Fig. 6—Analysis of Per Cent Power Factor Cable No. 12

$$\text{Per cent power factor} = A + B - C = 100\left(\frac{K}{C\,\omega} + \frac{K_1}{E\,C\,\omega} - \frac{K_1\,E_0}{E^2\,C\,\omega}\right)$$

proportional to the voltage and is the solid dielectric energy current. The second and third terms are the two components of the ionization energy current. The ionization energy current is a rectangular hyperbola having the current axis as one asymptote and a horizontal line $+\,K_1$ units from the voltage axis and parallel to it as the other asymptote. The ionization energy current thus approaches K_1 as a limit.

Capacitance Curves

The curve showing the increase in capacitance in cables after ionization begins may take three different forms. It may be practically a straight line, it may be concave upwards, or it may be concave downwards, Fig. 4. Fig. 2 shows that after ionization begins, the increase in capacitance of ionized air films is substantially linear.

In the cable, the ionized gas films are in series with the solid dielectric and in series with one another. Hence the resultant capacitance is a reciprocal relationship that is not simple. The significance of the capacitance curves of cables will be given later after obtaining further experimental data.

Conclusions

1. The power dissipated as ionzation loss in cable insulation is more harmful than the power dissipated in the solid dielectric.

2. At room temperature and up to from 250 to 300 volts per mil, the power factor and capacitance of cable insulating paper impregnated with typical compounds are essentially constant with variation in voltage provided nearly all occluded gas has been removed.

3. The relation of power loss to voltage in thin gas films is substantially linear for voltages above the ionization voltage.

4. In single-conductor cable insulation above the ionization voltage the relationship of ionization power to voltage is a curve which is concave upwards until all the gas films are ionized. With further increase in voltage the relationship becomes linear.

5. It is possible to analyze the power curve of cables into two components, one giving the loss in the solid dielectric, and the other giving the loss due to ionization. The ionization power curve so determined becomes linear.

6. It thus becomes possible to express the power curve by a simple equation and to extrapolate it if necessary.

7. The constants of the power equations may be criteria of cable quality.

8. The analysis of power loss into two components one giving the power dissipated in the solid dielectric and the other giving the power dissipated in ionization, is confirmed by tests made with glass cable models.

9. It becomes possible to express the power-factor curve by a simple equation, to analyze it into three simple components, and to extrapolate it.

10. The energy current of a cable can be analyzed into three simple components, a term nearly proportional to the voltage, a constant term, and a term inversely proportional to the voltage.

11. The character of the capacitance curves depends on the thickness and distribution of the gas films within the cable insulation.

The authors are indebted to D. W. Roper, F. M. Farmer, and W. F. Davidson, members of the Paper-Cable Research Committee, for their suggestions and counsel during the progress of this investigation; to the several cable companies for their cooperation in supply-

ing cable samples and compounds; and to Prof. H. E. Clifford of the Harvard Engineering School for his advice and suggestions during the progress of these investigations.

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Abridgment of

Magnetic Analysis*

BY RAYMOND L. SANFORD†

Non-member

Synopsis.—This paper presents a brief outline of the development and application of magnetic analysis for the nondestructive testing of iron and steel and their products. The subject is treated under the following headings: Historical development, Experimental results, Practical commercial applications, and Conclusion.

* * * * *

Introduction

The use of electrical methods for the measurement of non-electrical quantities, such as temperature, displacement, time, etc., is quite common. In the majority of such applications, these methods provide the most convenient and accurate means for making the desired determinations. The time is approaching, if indeed it has not already arrived, when magnetic analysis should be included in the list. The term "magnetic analysis" has been adopted to distinguish magnetic tests made with a view to their interpretation in terms of structure, mechanical characteristics, or soundness of ferrous materials from those made solely for the purpose of determining magnetic properties as such. The term connotes, therefore, not only the process of testing but also the analysis of the results from the point of view of mechanical characteristics. Although the development of such magnetic testing methods has not by any means reached a satisfactory state of perfection, their practicability has been demonstrated sufficiently well at least in a few cases to warrant the expectation that they will ultimately have a much wider application and thus meet the need which is becoming more and more urgent for a reliable nondestructive testing method.

That there is a close connection between the magnetic properties of ferrous materials and their other physical properties has long been recognized, and many investigations have been made for the purpose of discovering the nature of the connection. It is only in recent years, however, that investigations along this line have been undertaken with the definite object in view of developing practical magnetic testing methods for routine inspections and for the study of the phenomena associated with the thermal and mechanical treatment of steel.

It is the purpose of the present paper to trace briefly the development of magnetic analysis,[1] to indicate its present status and to suggest lines along which further investigation might profitably be directed.

Historical Development

Pioneers in the development of magnetic analysis were Burrows and Fahy, who, in the latter part of 1911, undertook at the Bureau of Standards under the joint sponsorship of the Bureau and the Pennsylvania Railroad, an investigation on spring steel. This investigation was continued over a period of about five years, during which time its scope was somewhat extended to cover preliminary experiments on the applicability of magnetic analysis to various forms of steel products. Three papers[1, 6, 8] were published giving the results of this investigation. Burrows also published a paper[3] in which the experimental evidence on the relationship between magnetic and mechanical properties recorded prior to 1916 was summarized. From the evidence presented he concluded that there was every reason to believe that the two sets of properties are intimately connected and that practical research and inspection methods could be developed. During this same period other papers[2, 3, 4] were published having a definite bearing on the problem.

In 1918 the American Society for Testing Materials authorized the formation of a technical committee to be known as Committee A-8 on Magnetic Analysis with Dr. Burrows as its Chairman. This committee was composed initially of investigators already working in the field, but from time to time its membership

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*Paper in full except for Bibliography omitted.

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1. For references see Bibliography in complete paper.

has been strengthened by the addition of members who have subsequently become actively interested in the development of magnetic analysis. The committee has functioned primarily as a clearing house for the interchange of ideas and experience among its members who have carried on individual investigations on various phases of the subject; but it has itself also carried out a number of investigations of a general and fundamental nature.[28, 32, 40, 51] A considerable proportion of the literature available on the subject of magnetic analysis has been contributed by members of this committee, either independently or through the auspices of the committee.

A second major source of technical literature is papers published by the Bureau of Standards. In general, the work of the Bureau has been directed along the more fundamental lines although some work on practical applications has been carried out.

Worthy of special mention is the work of deForest.[22, 24, 25, 31, 43] This ingenious experimenter has confined his attention in general to the development of methods employing alternating currents, and has brought out a number of applications of considerable interest and wide applicability.

Most of the work definitely belonging in the field of magnetic analysis has been done in the United States. There has however, been some interest in other countries. In this connection the work of Honda[7, 56] in Japan, and of Fraichet[29, 30] in France, should be especially mentioned. Honda has employed magnetic methods in the study of structural transformations occurring during heating and cooling, and, with his associates, has published a great many papers on the subject. He is probably the first one to use the term "magnetic analysis" but he employed it, in a limited sense, to denote only the single phase in which his work is preeminent. The work of Fraichet has consisted mainly of the study of relations between magnetic and elastic properties with special reference to the determination of the elastic limit by magnetic means.

Experimental Results

In discussing the results of investigations in the field of magnetic analysis, it will be found convenient to consider the following topics: Fundamental correlation, tests for general quality, detection of flaws, alternating-current methods, and thermomagnetic analysis.

Fundamental Correlation. In his paper published in 1916,[5] on the correlation of magnetic and mechanical properties of steel Burrows[5] enunciated what he believed to be the fundamental principle of magnetic analysis as follows: "There is one and only one set of mechanical characteristics corresponding to a given set of magnetic characteristics, and, conversely, there is one and only one set of magnetic characteristics corresponding to a given set of mechanical characteristics." He goes on to say: "Although there is no evidence to refute the preceding rather broad statement, the utility of this generalization is decidedly limited by the complexity of the relations due to the large number of variables and the lack of sufficient quantitative data. . . . Even with these limitations, magnetic testing, in conjunction with mechanical testing, may be expected to be of considerable value in determining mechanical properties." Unfortunately, some have made extravagant claims based on the first part of this statement while overlooking entirely the caution as to the inherent limitations due to the complexity of the relationships involved and the lack of fundamental data. As a rule, such claims are detrimental rather than advantageous, as failure to substantiate them has a tendency to discredit the whole proposition and deter some from entering the field.

In the attempt to discover fundamental correlations between the two sets of properties, it has been the general practise to make magnetic measurements by some well-known testing method on specially prepared samples. The results of these tests are then correlated either with the heat treatment or with the results of mechanical tests subsequently made on the same samples. Such correlation is not easy because the magnetic properties are in themselves complex. Attempts have been made to simplify the problem by using certain critical values, such as maximum permeability, induction corresponding to a specified value of magnetizing force, residual induction, coercive force and the like, as criteria. These attempts have not been very successful and it has been found necessary to consider the magnetic properties as a whole in drawing conclusions. Another lesson that has been learned is that it is generally not safe to draw too definite conclusions from the results of correlating magnetic properties with heat treatment alone, for we can never be assured that some accidental factor has not entered into the heat treatment and thus produced mechanical properties not normally associated with the specified heat treatment. Too much emphasis cannot be laid upon the necessity for proper metallurgical control in correlation investigations. The results of experiments in which this factor has not been adequately cared for must necessarily have but limited value in the quantitative sense.

Space does not permit a detailed discussion of the results of all the investigations recorded in the technical literature. These results, however, are in the main concordant and the following general conclusions may be drawn:

1. Any treatment which alters to a measurable extent the mechanical properties of a piece of steel at the same time appreciably alters its magnetic characteristics, though not necessarily to a corresponding degree.

2. The nature of the effect of various treatments on magnetic properties is generally similar for different types of steel; but this is not a universal rule, as notable exceptions have been observed.

3. Although the magnetic and mechanical properties appear to be functions of the same variables,—that is, composition and structure,—there are certain secondary effects, notably that of mechanical strain, which exert an influence on the magnetic properties out of all proportion to their effect on the mechanical properties. This is an important point which should never be overlooked in the search for laws of correlation.

Tests for General Quality. In their final application, tests for general quality must be applied to manufactured products of various shapes and sizes, and for this reason, a solution of the problem calls for a considerable amount of ingenuity in the design of apparatus for the testing of irregular shapes. In this type of application it should not be necessary to await the establishment of definite laws of correlation, for if pieces of steel having identical magnetic properties also have identical mechanical characteristics, it should only be necessary to compare the pieces under test magnetically with one known to have the requisite mechanical characteristics and which may therefore be taken as a standard of quality. A considerable number of investigations have been carried out as to the applicability of magnetic analysis for the testing of various products on this basis. Among the products investigated are cutlery, small tools, ball bearing races and balls, small case-hardened chain, and twist drills.

Encouraging results have been obtained in the majority of cases, but the obstacle in the way of practical application on a commercial basis is usually the effect of secondary influences as noted above. In other words, the test generally fails on the side of safety, but leads to the rejection of an excessive amount of good material. This should not be considered to imply that the outlook is hopeless, but only that the problem is not so simple as it might appear at first glance. The need for a satisfactory nondestructive test is so great that efforts in this direction should not be abandoned until every possibility has been exhausted. And the fact that successful application has been accomplished in even a few cases leads to the conviction that the general problem is not impossible of solution.

The Detection of Flaws. A large proportion of the failures of steel parts in service is due not to poor general quality of the materials but to the presence of hidden flaws or defects. It is for the detection and location of hidden flaws that a reliable nondestructive test is most needed. For this reason, a considerable amount of attention has been given to this phase of magnetic analysis, and at least one successful application has been recorded.[47] A large number of different products such as steel rails, rifle-barrel steel, rifle barrels, ball-bearing races, and welded chain have been the subject of study. One of the most important problems is that of the test of welds, for the applicability of welding is seriously limited by the lack of a suitable test for quality of the weld.

The usual test for the detection of flaws consists in an exploration for the determination of the degree of magnetic uniformity of the specimen. Abrupt changes in magnetic permeability may be the result of flaws; on the other hand, they may indicate the presence of internal strain or may result from relatively unimportant surface conditions. The problem therefore, at least in part, is to discover some way of differentiating between the indications due to strain and those due to actual flaw. A partial solution has been found[39] in the fact that variations due to strain are less in magnitude under high values of magnetizing force than for low or medium values. Unfortunately, the sensitivity to the effect of real flaws is materially decreased when high magnetizing forces are used. A great deal of work remains to be done on this important problem.

Alternating Current Methods. For routine inspection on a commercial scale, alternating current methods appear to have some practical advantages. The quantitative interpretation of the magnetic results is generally more difficult than for the ordinary direct-current methods, due primarily to the phase relations involved. With standardized equipment and arbitrarily chosen limits, however, these difficulties are of minor importance.

During the course of an investigation on high-speed steel carried on by Committee A-8 of the A. S. T.M.,[40] several methods were studied by different members of the committee. Although the results of the investigation left much to be desired in the way of definite correlations, the alternating current methods developed by deForest[24] seemed to offer the most encouraging field for further study. Two types of inspection have been developed. In the earlier form, the sample under test is compared with a standard by means of an inductance bridge using a separately excited a-c. galvanometer as a detector. By adjusting the phase of the current in the galvanometer field with respect to the induced voltages, it is possible to obtain readings on the galvanometer which depend mainly on the difference in permeability of the two specimens, the difference in hysteresis loss, or various combinations of the two factors. Thus it may be seen that in addition to speed in operation, the method offers great flexibility.

The second method[43] consists of the use of an oscillograph, preferably of the cathode ray type, with which the magnetic differences are shown graphically and appear as closed figures or loops of various shapes and sizes. By adjusting the phase of the time coordinate, it is possible to emphasize the difference in any particular part of the hysteresis loop. This method, first adapted to magnetic analysis by deForest, has been discussed with respect to its more theoretical aspects by Spooner.[44] From the evidence already presented, it would appear that these two types of alternating-current testing provide exceedingly valuable methods for the application of magnetic analysis both in the laboratory and on a commercial scale.

Thermomagnetic Analysis. Thermomagnetic analysis consists of the study of magnetic changes which occur during heating or cooling of a specimen. While not properly classed as a nondestructive test, thermomagnetic analysis should be considered as one phase of magnetic analysis. Its development and application have received little attention in the United States, but in the hands of the Japanese investigator Honda[7, 36] it has proved to be an exceedingly valuable tool for the study of the phenomena associated with the heat treatment of steel. Apparatus for the application of thermomagnetic analysis has been set up recently at the Bureau of Standards and it is hoped that this phase of magnetic analysis will be developed further.

Practical Applications. The methods of magnetic analysis have found some practical application both in the laboratory and in commercial routine inspection. In the laboratory, the applications have been of two kinds. As a research tool for the study of the constitution and structure of ferrous materials, it has found use which will undoubtedly be extended. Indeed, it may well be that in this connection magnetic analysis will find its most valuable application. Magnetic tests have been used also in the laboratory in conjection with long-time mechanical tests, such as endurance tests and tests upon the effect of elevated temperatures on mechanical properties. In tests of this sort, it is of great importance to be sure that all of the specimens used are initially in the proper condition and that they contain no flaws. Under such circumstances, the rejection of some good material is of less consequence than the acceptance of unsatisfactory material, since the results on such material may be not only valueless but even misleading.

In the realm of commercial routine inspection there are three outstanding examples; the inspection of small case-hardened chain,[22] the testing of small heat-treated forgings,[43] and the examination of steam turbine bucket wheels.[47] The first two are applications of the two types of alternating-current tests developed by deForest for the American Chain Company. The third mentioned method is a d-c. exploration test developed by the General Electric Company with the collaboration of Dr. Burrows.

In the testing of case-hardened chain, the inductance bridge method is used. The phase of the galvanometer field current is so adjusted as to give readings which experience has shown are proportional to brittleness. Readings which lie outside of certain specified limits indicate material which is either too brittle or too soft. This method for the control of the heat treatment of the manufactured product has been in use for over five years, several thousand individual specimens being inspected each day.

For the inspection of small heat-treated forgings, the oscillograph method is utilized. Experience has shown what form of loop indicates a satisfactory condition of the material. Variations from this form, greater than a certain amount, indicate defective material.

One form of apparatus for testing turbine bucket wheel forgings is shown in Fig. 1. The forging under test is rotated on its own axis between the poles of an electromagnet which can be adjusted to any given position on the radius of the circular forging. The magnetic flux passes across the air-gap between the pole tips, in which air-gap the disk is rotated. Any variation in the magnetic quality of the material in this air-gap is indicated by means of a sensitive galvanometer connected to coils on the specially designed pole tips. In most cases, the value of magnetic explorations for the detection of flaws and irregularities is limited by the effects of strain and other obscure conditions. This test, however, is not applied until the disk has been heat treated for the removal of strain, and machined to final dimensions, and hence, operates under the most favorable conditions. Although rejections are very few, in view of serious damage and sometimes even loss of life resulting from failure, it is exceedingly important that no defective piece be left in the finished machine.

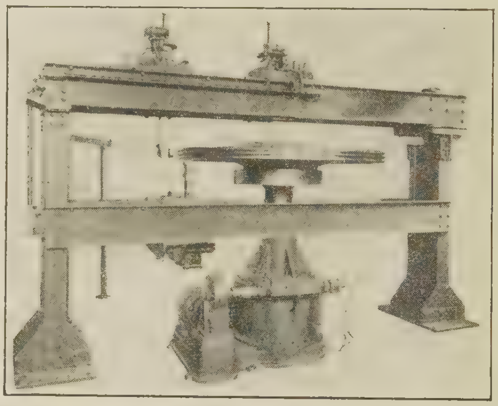

Fig. 1—Magnetic Analysis for Turbine Bucket Wheels.

Conclusions

From the foregoing rather cursory outline of the history and development of magnetic analysis, it is evident that the subject is one of great interest both from the point of view of commercial application and that of scientific investigation. The problem is not a simple one, as it involves not only the complex magnetic properties of materials, but also their composition and structure which determine the mechanical properties. The more rapid development of magnetic analysis has been hindered by a number of factors, some of which may be inevitable, but others of which might be obviated,—at least to some extent.

With relation to the magnitude of the problem in all its phases, the number of workers in this field is very small, and their activities have extended over such a broad area that general progress has been necessarily slow. More workers and better coordination would do much to remedy the situation. One circumstance

which may be inevitable, but which, nevertheless, operates to retard development, is the tendency for most workers to cover each discovery and application as fully as possible with patents. The potential new worker in this field,—particularly in industrial laboratories,—is somewhat uncertain as to his own status, and in this case the tendency is to await further development in the hope that such development as may interest him can be made on a secure basis.

Above all, the need is for more fundamental work. The possibilities in the way of practical applications are definitely limited by the lack of fundamental data. To be of maximum value, such fundamental investigations must be planned and carried out not only from the standpoint of the magnetic phenomena but also from the point of view of the metallurgical principles involved. This involves the closest cooperation between the magnetic investigator and metallurgist. One of the most important phases of the problem is the study of the so-called secondary effects, which greatly influence the magnetic properties without a correspondingly great effect on the mechanical properties.

The outlook, on the whole, is decidedly encouraging. Magnetic analysis has already proved of use in research on the treatment and structure of steel and for routine inspection on a commercial scale. There seems to be no reason why future progress should not be more rapid, and the hope that magnetic analysis may be found more and more useful as time goes on appears to be amply justified.

Abridgment of

The Diverter Pole Generator

BY E. D. SMITH[1]

Associate, A. I. E. E.

***Synopsis.**—This paper describes a new type of generator developed to overcome certain limitations inherent in the shunt and the compound generator, when used for charging batteries by the constant potential, the modified constant potential, and the floating methods.*

THE advantages of the constant-potential, the modified constant-potential, and the floating method of battery charging are quite generally recognized. These systems require a source of direct current of constant voltage.

The following characteristics are desirable in a constant potential battery charging generator.

1. It should preferably have a flat voltage curve which does not rise with increasing current at any point, otherwise stability of the correct charging voltage cannot be maintained without manual adjustment.

2. It should operate safely as a motor without speed-up or polarity reversal during feed-back from the battery.

3. It should preferably have a slight rise of voltage with decreasing current near zero load as a means for curbing a tendency to swing over to discharge during light loads.

4. When floated on bus-control circuits, which are subject to heavy momentary loads, at some point above full load the voltage should abruptly droop to protect the generator from the high peaks by shifting them to the battery, otherwise the generator will be damaged.

5. After the occurrence of these peak loads the generator voltage should return to its original value.

6. Commutation and efficiency should compare favorably with current standards.

The shunt generator is inadequate as its voltage falls too greatly with increasing load. Voltage regulators, when sufficiently sensitive, are necessarily delicate, and being susceptible to external conditions are difficult to keep properly adjusted.

The compound-wound generator fulfils some of the conditions but has its limitations. In case of feed-back from the battery the generator will motorize and run at an excessive speed and thus may cause damage. This is due to reversed current in the series coils bucking the shunt winding and lowering the field strength.

Also, the voltage curve, Fig. 1, of a flat compound generator is too convex for constant potential battery charging. With this typical curve it is difficult to charge at any rate between zero and that corresponding

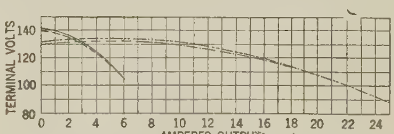

FIG. 1—VOLTAGE REGULATION CURVES OF 1½-KW. 130-VOLT SHUNT AND COMPOUND GENERATORS

———— increasing load shunt generator
- - - - - - - - decreasing load shunt generator
-.-.-.-.-. increasing load compound generator
-..-..-..- decreasing load compound generator

NOTE.—With shunt generator the voltage comes back slightly lower after an overload while the compound generators voltage comes back slightly higher after an overload

1. Rochester Elec. Products Corp., Rochester, N. Y.

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to the maximum voltage point, unless resistance is interposed between the generator and battery. In fact, any reduction of the charging current below the value corresponding to maximum voltage will usually be followed by a downward surge to discharge.

The voltage characteristic of the compound generator is curved, since the necessary magnetic changes produced by the series winding take place in the main

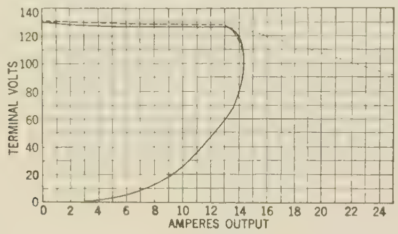

FIG. 3—VOLTAGE REGULATION CURVES OF 1½-KW. 130-VOLT DIVERTER-POLE CONTROL-BUS GENERATOR

——————— increasing load self excited
- - - - - - - - - - - decreasing load self excited
. . . . increasing load separately excited
NOTE.—The voltage comes back slightly higher after an overload

magnetic circuit in accordance with the magnetization curve of the machine. Usually in obtaining satisfactory design it is necessary to work at least partly on the curved portion of the magnetization curve and the compound generator reflects this curvature in its voltage characteristic.

The following is a description of a generator designed

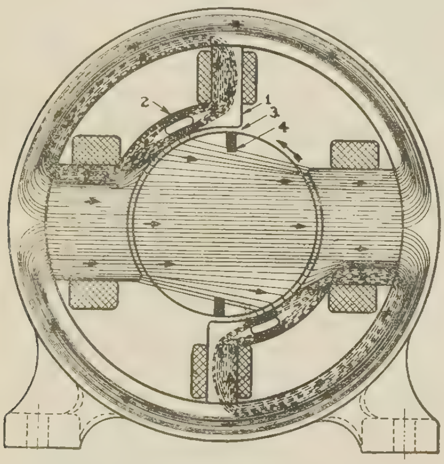

FIG. 4—MAGNETIC FLUX DISTRIBUTION AT NO LOAD

——————— main flux
- - - - - - - - - - - leakage flux

for the specific purpose of meeting the exacting requirements necessary in a constant potential generator for battery charging.

In this generator, as shown in Fig. 4, a small diverter pole, (1) spaced midway between the main poles, has a magnetic bridge connecting it to one of the main poles. Magnetic flux from the main pole will leak across this bridge to the diverter pole. A restricted section at 2 in this bridge performs two functions: first, it limits the leakage, and second it serves as a magnetic choke, whereby it is possible to regulate the magnetism passing to the armature from the inner face of the diverter pole at 3. This regulation is possible since practically the whole of the main field ampere-turns acting on the diverter pole are concentrated in overcoming the reluctance at this one restricted section, so that any reduction of the flux through this restricted section will release ampere turns expended here and raise the magnetic potential at 3 and consequently increase the magnetism passing to the armature at this point. At no-load, substantially all magnetic flux crossing the bridge will take the low reluctance path through the diverter pole (1) back to the frame without passing through the armature. A coil in series with the load circuit surrounds the diverter pole. As the load current increases, this coil, opposes and reduces the passage of magnetic flux through the diverter pole (1) to the frame.

The decrease of flux through the restricted section

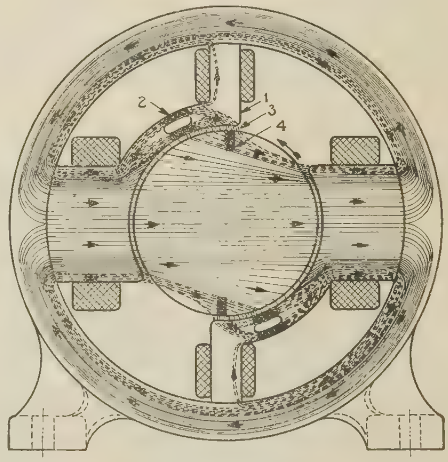

FIG. 5—MAGNETIC FLUX DISTRIBUTION AT FULL LOAD

——————— main flux
- - - - - - - - - - - leakage flux

at (2), attending any reduction of flux through the diverter pole, (1), produces, as above stated, a rise in the magnetic potential at (3). The result is that part of the magnetic flux leaking across the bridge will take the air-gap path to the armature at (3), Fig. 5, adding its value to the main pole flux and compensating for the voltage drop in the generator.

No variation of flux from the main pole to the armature occurs as there is no change in the magnetic potential at the main pole air-gap. This follows, since neither the main pole nor the frame is highly saturated and the small variation of flux through these parts, due to the change of flux through the diverter pole, produces no appreciable variation in ampere-turns of the main field excitation expended on this part of the main magnetic circuit.

A flat voltage curve is obtained since the magnetic changes produced by the series winding take place only in the diverter pole (1), and as the flux density here is kept low these changes occur on the low straight portion of the magnetization curve, thus eliminating most of the curvature from the generator voltage characteristic.

These magnetic changes occurring in the diverter pole take place from a higher to a lower density on increasing the current output of the generator. This is the reverse of the occurrence in the compound generator, and the effect is to invert whatever part of the magnetization curve appears in the generator voltage characteristic, producing a concave instead of a convex voltage curve. By the proper adjustment of the diverter pole winding an almost straight curve is obtained with a slight rise on approaching zero load.

When motorizing, the main field strength is maintained substantially at its full value, as reversed current in the series coil can divert no further leakage due to saturation of the bridge restriction at (2). Also, any tendency for the diverter pole (1) to establish itself as an independent pole opposite in polarity to the main pole is limited to a safe value since the diverter pole already carrying the leakage flux quickly approaches saturation at any increase of flux through it, and safe operation as a motor is assured.

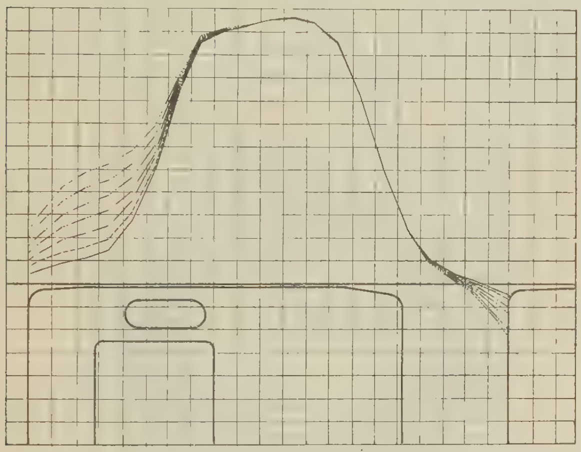

Fig. 6—Flux Distribution Curves

When excitation of diverter poles is increased, armature carrying no current, brushes up, with main fields separately excited at constant value

———— 0 amperes in diverter pole coils
- - - - - - - - - - 5 amperes in diverter pole coils
- . - . - . - . - . 10 amperes in diverter pole coils
- . . - . . - . . - 15 amperes in diverter pole coils
- . . . . 20 amperes in diverter pole coils
———— . . . . ——— 25 amperes in diverter pole coils
———— . . . . . ——— 30 amperes in diverter pole coils

At some value of the load current the ampere-turns on the diverter pole equal those on the main pole and at this time the magnetic flux leaking across the bridge to the diverter pole is all re-diverted across air-gap (3), and there is no further leakage flux for an increased current to re-divert to the armature.

What occurs when the load is increased beyond this point is best illustrated by some recent tests.

The machine tested was a 1½-kw. generator, designed for floating with a 129-volt bus control battery. For the tests, this generator was equipped with a pair of movable exploring brushes by which the voltage around the commutator could be checked (step by step) and the flux distribution determined.

Fig. 6 shows the flux distribution when the generator was operating with brushes up, shunt fields separately excited at a constant value and various currents passed through the diverter pole coils. This shows that the regulating flux is produced only at the diverter pole face, the flux from the main pole remaining practically constant.

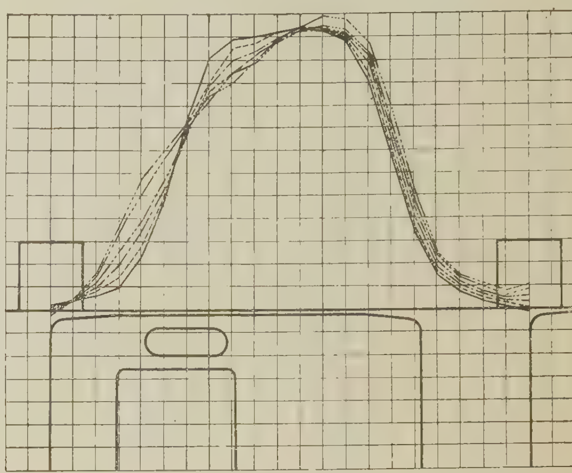

Fig. 7—Flux Distribution Curves

When output is increased up to the voltage cutoff point at 14 amp. with main fields self excited

———— 0 amperes generator output
- - - - - - - - - - 3 amperes generator output
- . - . - . - . - . 6 amperes generator output
- . . - . . - . . - 9 amperes generator output
- . . . - . . . - 12 amperes generator output
- . . . . - . . . . - 14 amperes generator output

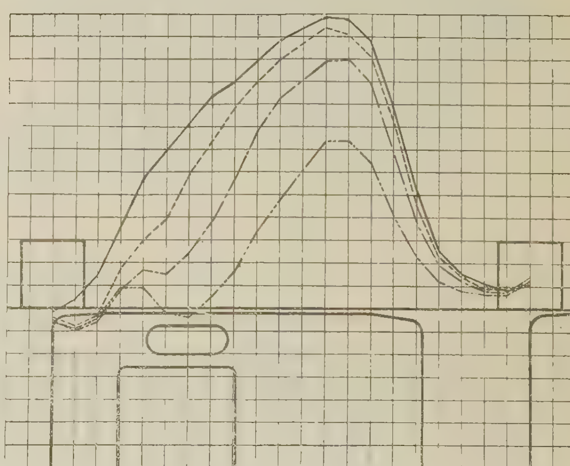

Fig. 8—Flux Distribution Curves

When diverter pole generator is loaded beyond the voltage cutoff point at 14 amp. with main fields self-excited. Although the load was increased the amperes decreased due to the falling voltage

———— 14 amperes generator output
- - - - - - - - - - 14.4 amperes generator output
- . - . - . - . - 14 amperes generator output
- . . - . . - . . 11.2 amperes generator output

Figs. 7 and 8 illustrate flux distribution under load, Fig. 7 showing flux changes up to the voltage cut-off point of 14 amperes. This shows the effect of armature reaction in the crowding of the main field to the right and in the partial suppression of the diverter pole field.

Fig. 8 shows that with any increase in the load current beyond the cut-off value of 14 amperes, instead of an increase in the diverter pole field there is a definite an decided collapse. With this collapse of the diverter pole field the terminal voltage falls and hence the main field excitation is reduced which accounts for the reduction of the main pole flux. The solid line of Fig. 3 shows the voltage regulation for this machine.

It appears from these tests that when the ampere-turns on the diverter pole exceed those on the main pole, the flow of magnetism through the diverter bridge is reversed. Magnetism now flows from the diverter pole to the main pole and not from the main pole to the diverter pole. Under these changed conditions the magnetizing action of the armature assists the flow of magnetism through the bridge instead of opposing it. In fact, under heavy load, the magnetism does actually reverse and pass from the armature to the bridge, and joining with the main pole flux, passes back to the armature at the rear pole tip, constituting cross magnetism, while the magnetism from the diverter pole crossing the bridge flows backward through the main pole to the frame returning to the diverter pole without passing through the armature.

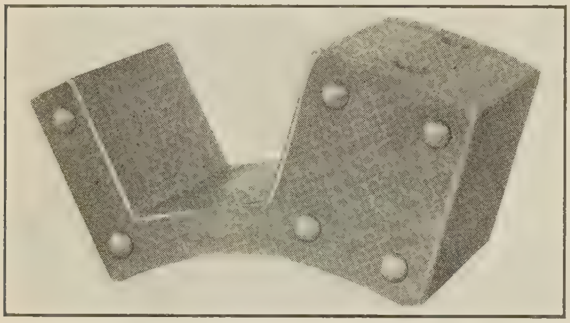

Fig. 12—Diverter Pole

The hole in the bridge does not appear as the two end laminations are punched without this hole the inner laminations have the hole as shown in Figs. 4 and 5

When the load on the generator decreases a descending excitation is produced in the diverter pole coils and due to the effect of hysteresis this descending excitation leaves a slight residual magnetic field passing from the diverter pole face to the armature. This accounts for the voltage being slightly higher after an overload than before, as shown in Fig. 3.

Good commutation is assured as the diverter pole provides a commutating field of the correct direction for improving commutation and this field varies with the current output as in an interpole generator.

The efficiency will equal that of a similarly rated compound interpole generator since the excitation on the main poles will equal the shunt and series excitation and diverter pole excitation will be the same as that of the interpole of the compound generator.

Figs. 12 and 13 illustrate the pole and the complete field assembly of the diverter pole generator.

The characteristics of this generator are desirable for many battery charging applications.

In telephone exchanges when floated in parallel with the main battery, the generator maintains the voltage within the close limits required for correct operation of the equipment and furnishes the current directly to the exchange without its passing through the battery. Considerable economy is effected by the saving of power and in the increased life of the battery, and also by a saving of labor through the elimination of the necessity of manual voltage regulation.

When several batteries are charged in parallel by the constant potential or modified constant potential method, as in recharging of vehicle and automobile batteries, the advantage of constant voltage, coupled with the ability to operate safely as a motor without

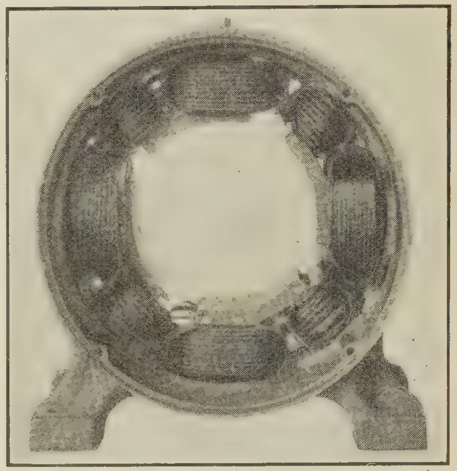

Fig. 13—Diverter Pole Field Assembly

polarity reversal or speed up during power failure is quite apparent.

In control bus operation, where a small generator is connected and operated continuously in parallel with a battery for switch operation, all of the desirable characteristics of this generator are utilized to advantage.

The flat voltage characteristic insures maintenance of correct floating voltage under varying load conditions with minimum supervision.

The ability to motorize safely without speed up or polarity reversal gives security during power interruptions.

The slight rise in voltage with decreasing current near zero load and the recovery momentarily to a slightly higher voltage after an overload combines to produce the desired stability of the correct floating voltage at the light load which constitutes the normal operating condition.

The sharp droop in the voltage just above full load amply protects both the generator and motor from danger of overload during switch operation.

The high voltage recovery after overload prevents the gradual diminishing of the generator voltage and

consequent discharge of battery that occasionally happens with a shunt generator from the repeated overloading occurring in this service.

An advantage of the constant-voltage characteristic is that the battery is more quickly charged after it has been carrying load, since the battery is charged at a higher rate than with a generator of drooping voltage characteristic. This is an additional advantage as the higher charging rate tends to keep the battery, particularly the negative plates, in good condition. It also appears that the slight variations which may occur in the frequency of the power circuit should produce a beneficial effect in the battery when floated on a diverter pole generator. The voltage of the generator will follow these frequency variations and either slightly charge or discharge the battery as these variations are above or below normal. This will give a desired amount of activity to the negative plates without overcharging the positive plates.

The battery discharge during switch operation is not so great where the diverter pole generator is used, since the generator supplies the current demand up to its full load capacity, while the shunt generator gives little assistance to the battery at this time. This means that a higher bus voltage will be maintained during switch operation with the same size battery when floated with a diverter pole generator.

Several thousand of these generators have been built and are operating on various battery charging applications, and their performance has justified the conclusion that the generator has many advantages where the constant potential, modified constant potential, or the floating method of charging is used.

The outstanding feature of this machine is its ability to give constant voltage with varying load and still be safe from speeding up or polarity reversal during feedback from the battery. However, the other characteristics,—*viz.*, the inverting of the voltage curve which makes for stability of the charging voltage, the high voltage recovery after overload insuring voltage stability on light loads, and the drooping of the voltage on overload which protects it from serious overloading,—contribute to its adaptability to the battery charging field.

Abridgment of

Carrier Telephone System for Short Toll Circuits

BY H. S. BLACK,[1] M. L. ALMQUIST[2] and L. M. ILGENFRITZ[2]

Associate, A. I. E. E. Associate, A. I. E. E. Non-member

Synopsis.—*This paper describes a new carrier telephone system which is designed for use in the telephone plant as a substitute for open-wire line construction for circuits of shorter lengths than could be economically spanned by multi-channel types of carrier systems in use for longer distance transmission. This new system, which is known as the type D carrier telephone system, provides one additional talking circuit per pair of wires. The equipment is adapted to provide facilities quickly, and is capable of being moved readily from one location to another when temporary facilities are desired. The system employs a novel and original modulation circuit which is fully described in the complete paper.*

* * * * *

Introduction

ONE of the important developments in telephone engineering during the last decade has been the practical application of high-frequency currents for the transmission of telephone and telegraph messages over circuits simultaneously carrying other traffic. For the transmission of speech by this method, the band comprising the frequency components in the voice of the speaker, which in the ordinary telephone circuit is transmitted by electrical currents of the same frequencies, is translated into a band of high-frequency currents. These high-frequency or "carrier' currents are above those transmitted by the ordinary voice-frequency channel, and so may be sent over a pair of wires that is being used for the transmission of speech frequencies. At the receiving end, the bands of high-frequency currents are separated from each other and from the voice currents on the same pair of wires by electrical filters, so that each delivers its message independently.

Since 1918, the date of the first commercial installation of carrier telephone equipment, engineering and installation of carrier systems has progressed steadily. In the paper on *Carrier Systems on Long Distance Telephone Lines,*[3] it was shown how developments of recent years have greatly extended the use of carrier telephony on the longer circuits in the Bell System. There is also a considerable field of use for carrier telephony on the shorter open-wire toll circuits; that is, those ranging upward from about 50 mi. in length.

1. Systems Development Department, Bell Telephone Laboratories.

2. Department of Development and Research, American Telephone and Telegraph Company.

3. *Carrier Systems on Long Distance Telephone Lines*, by H. A. Affel, C. S. Demarest and C. W. Green. October TRANS., Quarterly, 1928, A. I. E. E., p. 628.

Presented at the Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928. Complete copies upon request.

The type D carrier telephone system has been developed to fill this need.

General Arrangement and Functioning of System

In order to provide a carrier system which would be sufficiently low in first cost and maintenance to effect economies when used in place of wire construction for these shorter circuits, special consideration has been given to reducing the amount of apparatus required and at the same time providing a system of such stability that very little maintenance would be required. This has been accomplished by making the system a single-channel system,—one which provides only one additional talking circuit per pair of wires,—by employing comparatively low carrier frequencies, and by including several new design features. The provision of only a single channel results in a simpler and less expensive design for the filters; the use of low carrier frequencies results in decreased line attenuation and reduces the cost of line transpositions and carrier loading which may be required; while the new design features are of such a nature as not only to simplify the apparatus but to increase the stability of the circuit as well. Daily adjustments necessary with carrier systems operating over greater distances have been eliminated. The complete equipment for each system terminal is assembled as a unit which is wired and tested at the factory before shipment, thereby reducing engineering and installation costs.

The new electrical features which have been incorporated in this system consist principally of (1) the use of an arrangement for producing carrier current whereby modulators and demodulators are self-oscillating; that is, the same vacuum tubes function both as oscillators and modulators or as oscillators and demodulators, thus economizing in the use of tubes and power; (2) the use of a new method of modulation and demodulation requiring the expenditure of a relatively small amount of plate battery power; (3) the elimination of grid batteries in the modulator and demodulator circuits by the use of grid current to produce grid biasing voltage; (4) the use of the modulator-oscillator circuit as a source of signaling current supply; and (5) the use of a ballast resistor to maintain the filament current within suitable limits. These new arrangements have resulted in economy in equipment as well as in a system of high stability. Economies also have been effected by the use of improved types of paper condensers in place of mica condensers in certain parts of the circuit, and by the use of unpotted coils where the requirements are such as to permit of this being done.

Like other recent carrier systems, this one uses different high-frequency bands for transmission in opposite directions. It is a carrier suppressed system, and a single sideband only is transmitted. As shown in Fig. 1, the lower sideband of a carrier of 10,300 cycles is used for transmission in one direction, and the lower sideband of a carrier of 6867 cycles for transmission in the opposite direction.

The type D carrier telephone system has been provided in two general arrangements; the first employs certain basic equipment only and is suitable for operation over circuit lengths up to about 125 mi.; the second employs the basic equipment together with terminal amplifiers and other additional equipment and is suitable for use for circuits up to about 200 mi. in length. The latter arrangement, which is known as the type D-A system, is also used in some cases for circuits under 125 miles in length in order to equalize transmission levels with respect to those of other carrier systems operating on the same pole line. This is sometimes necessary because the normal levels of long-haul carrier systems are higher than those provided by the type D system without an amplifier. Also, there are certain circuit layouts involving type D systems only, which may require level equalization by means of the amplifier.

A schematic of one terminal of a basic type D system is shown in Fig. 3. When subscribers are connected

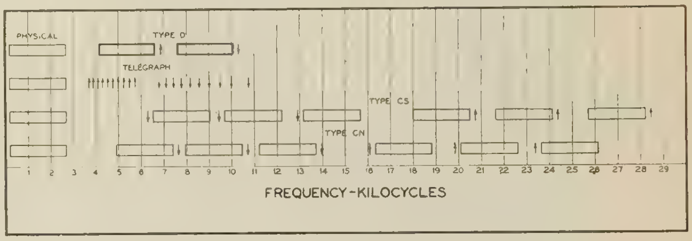

Fig. 1—Frequency Allocation of Type D System

to the two terminals of the carrier circuit, speech frequencies from the talking subscriber pass into the hybrid coil, and are impressed upon the grids of the modulator tubes. The application of speech frequencies to the modulator, with carrier frequency present, results in modulation, the principal products of which are the upper and lower sidebands. By means of the balanced connection of the modulator output transformer, the carrier frequency is almost entirely suppressed and only a negligible amount appears in the output circuit. The output from the modulator passes to the modulator band filter where the upper sideband and other unwanted frequencies are suppressed and the lower sideband is permitted to pass on to the line through the high-pass line filter. The low-pass line filter prevents the high-frequency current from passing at the local terminal to a subscriber who may be talking on the voice-frequency line circuit on which the carrier is superimposed.

At the receiving terminal, the transmitted sideband passes through the high-pass line filter and the demodulator band filter to an input transformer which impresses it on the grids of the demodulator tubes. Application of these sideband frequencies to the demodulator, with the carrier frequency present, results

in a reproduction of the voice frequencies applied at the sending end. The various undesired high-frequency currents present in the output of the demodulator are suppressed by the low-pass filter in the output circuit. The voice currents pass to the hybrid coil and thence to the switchboard and the listening subscriber.

The design of the modulator and demodulator circuits is such that a novel and original scheme of modulation and demodulation results. Grid biasing voltage is obtained by rectifying in the grid circuit a small portion of the applied carrier wave. The two tubes oscillate in parallel, the amplitude of the oscillations being controlled by the design of the oscillator coil instead of the usual feed-back resistance, and the portion of the carrier wave rectified is sufficiently small so that the grid biasing voltage is nearly equal to the peak value of the oscillations. Referring to Fig. 26, it will be seen that the grid biasing voltage for the modulator is -100 volts, whereas, the usual grid voltage, if this type of tube is operated as an ordinary plate circuit modulator is -18 volts. Due to this high negative grid potential, only a portion of the carrier and voice voltages applied to the grids is effective in varying the plate current. The result of a mathematical analysis of this portion of the grid voltage is shown in Fig. 32. This figure is a diagram of voltages, which, if applied to the grids as shown, would produce the same result in the plate circuit as the carrier and voice voltages actually applied. The frequencies that are important in controlling the production of sideband differ from those in the older types of modulators. In this case, for maximum efficiency the load impedance should be zero at all frequencies except the sideband desired, at which frequencies it should equal the resistance of the tubes at the operating point. A full description of the theory of operation of these circuits is given in the complete paper.

The arrangements for signaling are also shown in Fig. 3. The method of signaling is similar to that employed in the 1000-cycle signaling system used on wire circuits. It differs in that signaling current is obtained by changing the connections of the modulator during the ringing period so that a separate source of 1000-cycle signaling current is not required. In order to signal over the carrier circuit, the modulator is unbalanced and the oscillator frequency reduced by 1000 cycles. The resulting high-frequency output is then interrupted at a 20-cycle rate. The receiving portion of the signaling circuit consists of an arrangement designed to respond to 1000-cycle current interrupted at a 20-cycle rate.

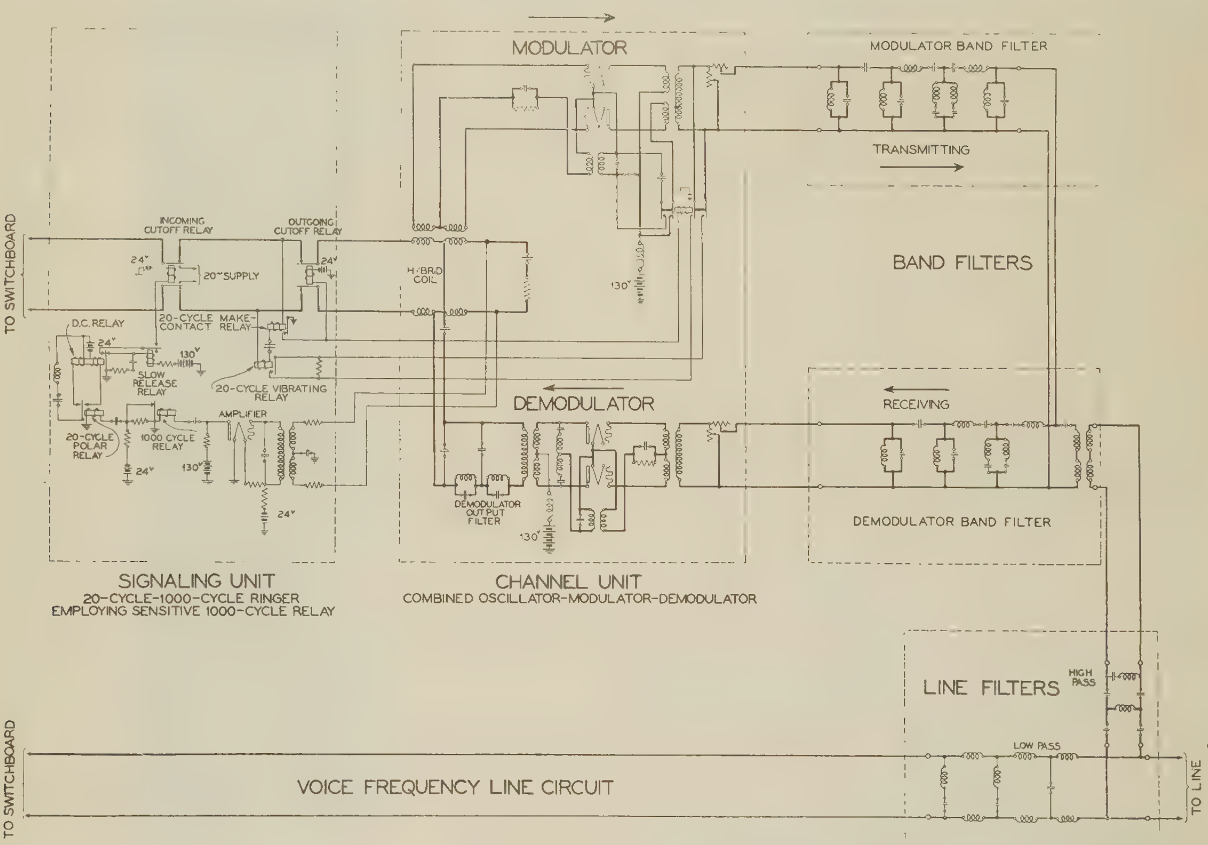

Fig. 3—Schematic of Terminal of Basic Type D System

Transmission Considerations

The use of relatively low carrier frequencies has been an important factor in effecting economies. Low carrier frequencies, in addition to reducing the amplifi-

cation which the equipment must provide, insure better transmission stability over the line. Low carrier frequencies reduce the carrier loading and line transpositions which may be required. Representative transmission characteristics of the band filters and line filters are shown in Fig. 11.

The high degree of inherent stability which has been secured in the design of the system has made it practicable to omit apparatus for the adjustment of amplification, frequency, and filament current usually provided with carrier equipment, thereby simplifying the system and reducing its cost. The variations of transmitting and receiving amplification with plate battery fluctuations from 125 to 135 volts are not more than 0.1 TU. Variations in transmitting and receiving amplification with filament battery fluctuations from 20 to 28 volts are even less. Combined transmitting and receiving amplification changes with tube changes do not exceed approximately 1 TU. These are, however, of lesser importance as tubes are changed very infrequently. This high degree of stability results from the self-compensating properties of the self-oscillating circuits.

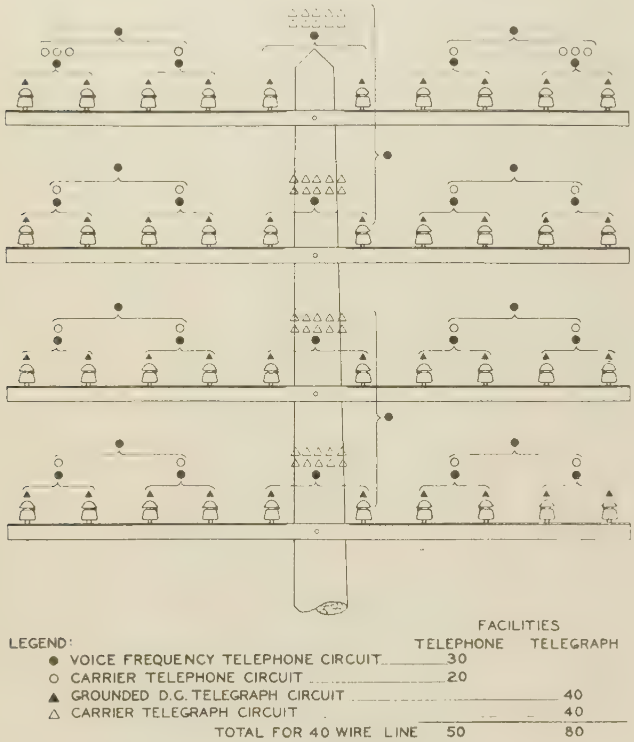

Fig. 6—An Arrangement of Communication Facilities on Pole Line of Four Crossarms

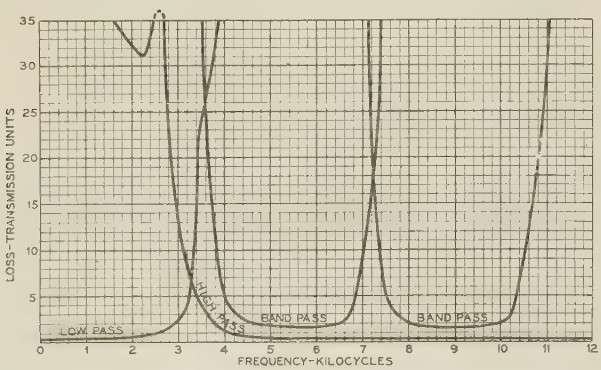

Fig. 11—Representative Filter Transmission Characteristics

A comparatively inexpensive transposition system has been designed to permit the maximum number of type D systems to be operated on the same pole line. This system provides for the use of type D carrier systems on as many as four crossarms. When it is applied to lines on which no other type of carrier facility will be operated, it permits the use of basic type D systems on all pairs with the exception of the pole pairs. With slight modifications, it provides for the operation of two three-channel type C-S carrier telephone systems,[3] one system on each of the outside phantom groups of the top arm, and, in addition, either a carrier telegraph or a type D–A carrier telephone system on the other pair of each of these phantom groups. Type D–A systems may also be operated on all other pairs of the line except on the pole pairs. Carrier telegraph systems may generally be operated on one or more of the pole pairs. The former transposition arrangement for the basic system, therefore, permits the operation of a total of 16 type D systems on a four-arm

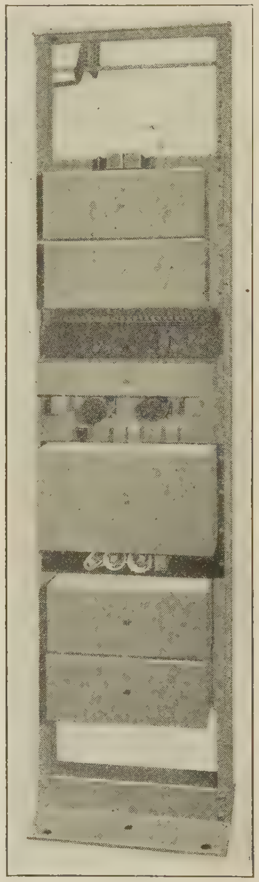

Fig. 13—Typical Assembly of Type D Carrier Terminal on Floor Mounted Rack

lead, and the latter arrangement with the long-haul systems permits the operation of two three-channel carrier telephone systems, 14 type D–A systems, and, in favorable cases, four 10-channel carrier telegraph systems on the same number of pairs, in addition to the grounded d-c. telegraph and the telephone facilities ordinarily obtained. Fig. 6 illustrates the relative positions of these facilities on the four crossarms.

Equipment Features and Typical Installations

The equipment for the basic type D system has been divided into five principal units: the signaling unit, channel unit, modulator band filter, demodulator band filter, and line filter set. The apparatus for each of these units is assembled on a panel 19 in. wide and of sufficient height to provide the required mounting space. These panels are mounted on a rack and wired together, the leads which go to points outside of the bay being wired to a terminal block located at the

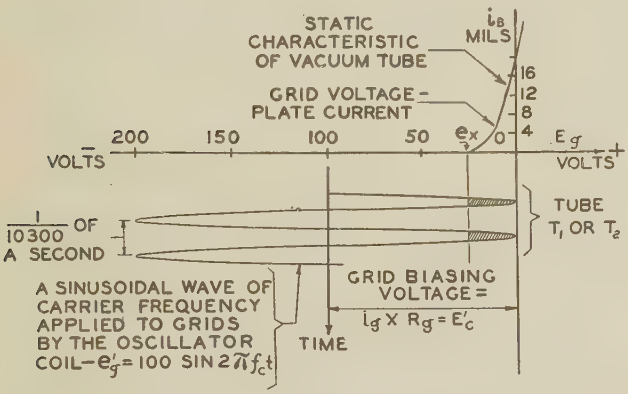

Fig. 26—Approximate Relation of the Tube Characteristic to the Grid Voltage in the Self-Oscillating Modulator of Fig. 21. No Speech Input

top of the rack. The wiring required at the time of installation consists only in cabling from this terminal block to the distributing frame and to the sources of power supply.

A typical assembly of a type D carrier terminal is shown in Fig. 13. This arrangement employs a floor mounted rack approximately 7 ft. high and includes all of the equipment comprising the carrier terminal with the exception of the power supply. The two box-like units near the bottom of the rack are the band filters. Directly above the band filters are the channel unit, signaling unit, relay adjusting unit, and jack panel, in the order named. Above the jack panel are the line filters and certain balancing equipment which is required when voice repeaters are used on the voice-frequency circuit on which the carrier system is superimposed, or on the circuit obtained by the carrier system. This particular assembling is of advantage in temporary installations and in offices of low ceiling heights. Where greater economy in floor space is desired, an assembly which provides the equipment for two type D carrier terminals on a rack 11½ ft. high is used.

Similar assembly arrangements are provided for the type D–A system. In this case, an amplifier and an auxiliary filter panel are required in addition to the apparatus listed above.

Due to the features of its design and arrangement whereby it may be furnished as a complete self-contained equipment requiring relatively little engineering and installation work, the type D system is useful in providing facilities quickly, and, where temporary facilities are required, is capable of being readily moved from one location to another. This has already proved to be an advantage of some importance to the

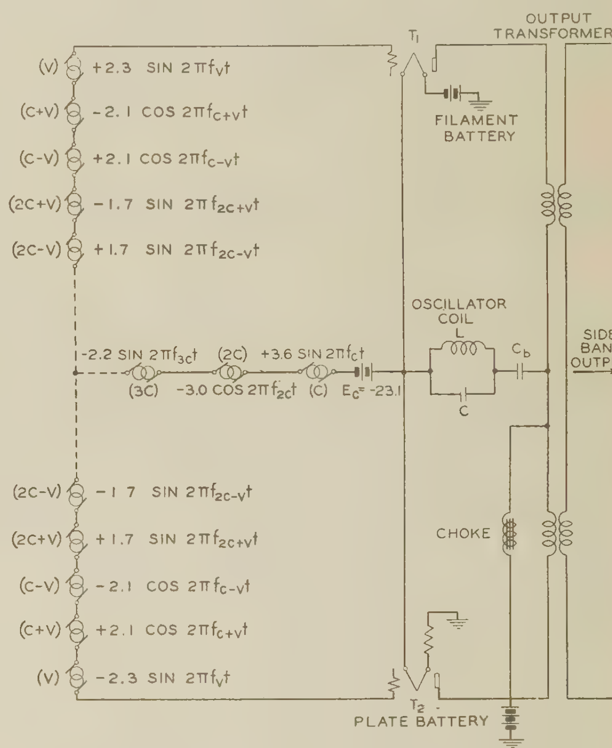

Fig. 32—A Diagram of Voltages which if Applied to the Grids as Shown Produce the Same Result in the Plate Circuit as the Carrier and Voice Voltages in the Modulator of Fig. 3

telephone companies. The establishing of facilities on an emergency basis during the recent flood in New England is one example of this sort. Another occurred in New York State when after a line break had interrupted service over the normal route, two terminals were transferred quickly from one office to another thereby increasing the facilities via the latter office. A number of cases have occurred also in which type D equipment has been used to provide facilities for sudden growth in oil fields. While this use of the system forms a comparatively small part of its field of application, it is an advantage which, at times, may be of considerable importance. The principal use of the system is to provide additional facilities which are required as a result of permanent traffic growth where these can be

provided more economically by means of this system than by stringing additional wire.

Conclusions

With the development of the type D carrier telephone system, the art of carrier telephony has been brought to the point where it can be used to advantage in providing telephone facilities for much shorter circuits than have been economical heretofore. Type D systems now in service are operating principally over distances of about 75 to 200 mi., although in certain cases where the conditions are favorable, systems as short as about 50 mi. are in use. The exact distance beyond which it is more economical to employ this carrier system than to string additional wire, is, of course, dependent upon the conditions applying to each particular case. For greater distances, up to the limit of the operation of the system, the economies effected by its use increase quite rapidly.

The performance of the type D system is comparable with that of a corresponding wire circuit. The form of the equipment is such that it is well adapted to the various office conditions, it can be used to provide facilities quickly, and can be transferred readily from one location to another in case of emergency.

On June 1, 1928, approximately 125 type D carrier telephone systems were in service and operating satisfactorily. It is expected that by the end of 1928 the number of systems in use will have increased to about 225. The growth in short open-wire toll circuits is such that there is a considerable field of application for this system.

Abridgment of

Reduction of Sheath Losses in Single-Conductor Cables

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Member, A. I. E. E.

and

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Associate, A. I. E. E.

Synopsis.—*The use of single-conductor lead-covered cable for high-voltage, three-phase transmission lines results in sheath losses ranging from 25 to 300 per cent of the conductor losses for cables installed in separate ducts, unless special methods for the reduction of the losses are used. Some of these methods, while practically eliminating sheath losses, cause a-c. sheath potentials which may be injurious. In this connection, the authors have developed a new bonding scheme and a new bonding device both of which appear to have marked advantages.*

This article consists of a general discussion relative to the reduction of sheath losses, with special reference to laboratory tests, and to field work on 132 mi. of single-conductor cable of the Commonwealth Edison Company.

The economics of sheath losses and of the methods for their practical elimination are discussed. The theories of sheath losses and induced voltages are outlined and correlated, and new formulas and curves are developed. An analytical and graphical comparison of sheath bonding connections is presented. Investigations are reported on tests regarding the nature and extent of possible corrosion of sheaths caused by a-c. sheath voltages.

I. Introduction

As shown by an increase from 4 to 8 per cent of the total installed cable in the United States from 1926 to 1927[2] the use of single-conductor, lead-covered, underground cable for high-voltage three-phase potentials has been growing rapidly. If the cables are installed in separate ducts and operated with solidly bonded sheaths, the sheath losses will range from 25 to 300 per cent of the conductor losses, thereby considerably decreasing the carrying capacity and increasing operating costs. If the sheaths are made discontinuous and bonded in special ways to prevent sheath currents, then problems arise to provide satisfactory insulating joints, bonding apparatus and bonding connections and to limit the sheath corrosion that may be caused by unneutralized sheath voltages.

A new device,—namely, a three-phase sheath bonding transformer,—and a new bonding connection, which appear to have marked advantages over previous bonding devices and connections, have been originated and developed by the authors.

A general consideration of the entire problem of eliminating sheath losses and reducing sheath voltages on single-conductor a-c. cables will be attempted in this paper with special reference to the work done by the Commonwealth Edison Company in the past two years on approximately 132 mi. of 12- and 66-kv., 60-cycle cables.

II. Economics

The elimination of the sheath losses in 750,000-cir. mil, single-conductor, 66-kv. three-phase, 60-cycle cables, installed in conduits with other cable, increases the average yearly carrying capacity from approxi-

1. Head Engineer and Asst. Head Engineer, Technical Division, Street Department, Commonwealth Edison Company.

2. Cable Operation; Reports of Underground Systems Committee, N. E. L. A., 1926-7 and 1927-8.

Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

mately 50,000 to 60,000 kv-a., or about 20 per cent. Since the total investment cost of the installed cable is approximately $60,000 per mile of line, the increased investment value due to the elimination of sheath losses is approximately $12,000 per mile of line. An additional saving is made in the cost of reduced sheath losses which is about $1000 per mile of line per year, assuming 55,000 kv-a. average yearly rating and a 60 per cent load factor. Capitalized at 10 per cent per year, this represents an additional investment saving of $10,000 per mile of line.

Extra investment is required for (1) insulating joints, (2) insulated cable saddles and bond wire, (3) special fireproofing to minimize corrosion due to a-c. voltages, and, in some cases, (4) bonding devices such as reactors or transformers. The additional investment cost required per manhole is about $65 for the first three items and $125 to $250 for all four items. Using even all four items and assuming 12 manholes per mile, the average additional cost of eliminating sheath losses is about $1500 per mile. This cost is only one-eighth of the increased value of a 66-kv. line due to the increased rating, or, in effect, the cost of the losses saved would pay for the additional investment in one or two years.

For 12-kv. leads feeding the transformers of the 66-kv. lines, the standard practise in Chicago is to install three 1,750,000-cir. mil cables per phase in one conduit. In this case the increase in carrying capacity obtained by the elimination of sheath losses is about 70 per cent.

Induced sheath voltages are proportional to cable length, and because of a-c. electrolysis, it may be destructive to operate with sheath voltages exceeding 12 volts to ground. Without bonding devices, this limit is reached with about 500-ft. lengths on the 66-kv. cables, or, under practical conditions, with about 13 manholes per mile. If a series type of bonding device, (Fig. 2E), or a cross-bonded star-ground type of connection (Fig. 2G) is used, the lengths may be increased 100 or 60 per cent, respective y, without increasing the voltages between sheaths and ground.

The Commonwealth Edison Company has found it desirable to increase the maximum conduit lengths up to the length of a standard city block; that is, about 660 ft. This reduces the average number of manholes per mile from 13 to 9 and thereby saves over $4000 per mile of conduit on account of reduced number of manholes and joints, and costs of installation. The increased investment cost for the necessary bonding devices for connection Fig. 2G is approximately $600 per mile.

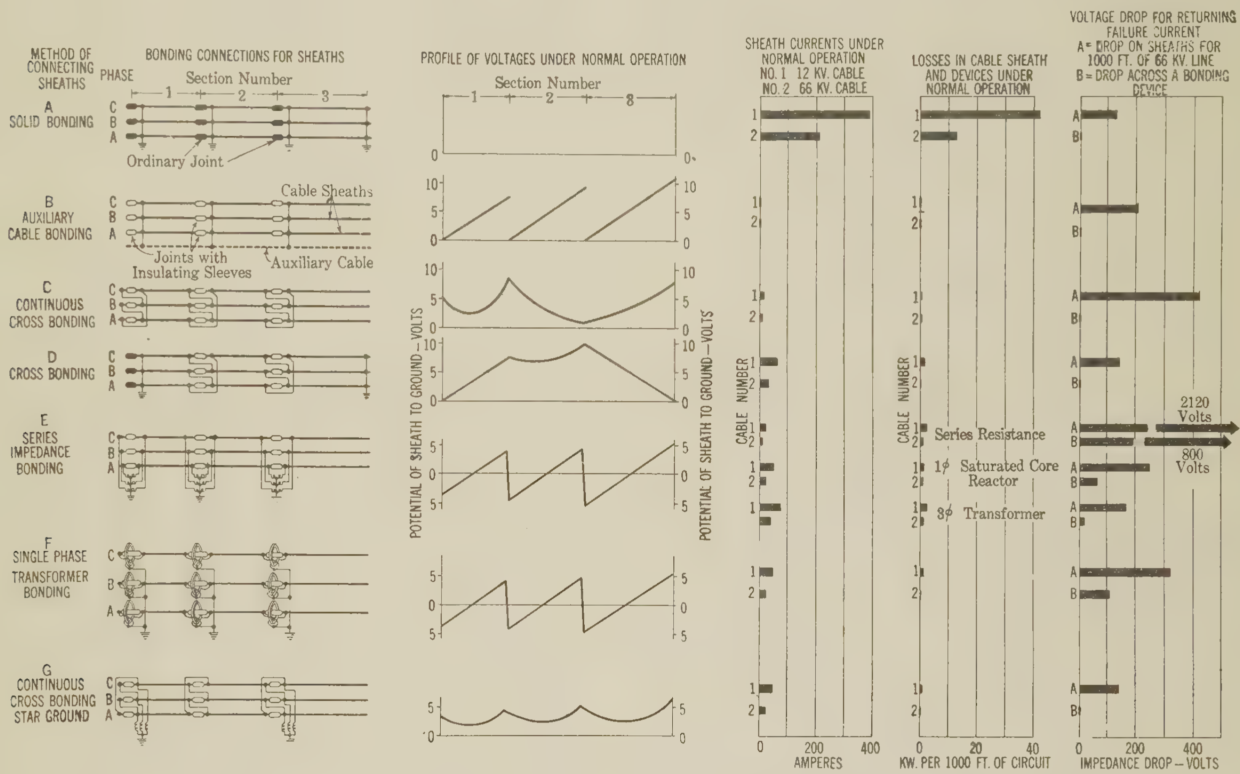

FIG. 2—COMPARISON OF CONNECTIONS AND RESULTING SHEATH VOLTAGES, CURRENT, AND LOSSES FOR 12-KV. AND 66-KV. THREE-PHASE 60-CYCLE SINGLE-CONDUCTOR CABLES

1. Lengths of sections 1, 2, and 3 are 330, 400 and 470 ft. for 66-kv. cables and 55 per cent as long for 12-kv. cables
2. Cable (1) 1,750,000 cir. mils, 12 kv.; flat arrangement with 6 in. between centers; 20,000-kv-a. load per circuit
3. Cable (2) 750,000 cir. mils, 66 kv.; flat arrangement with 6 in. between centers; 60,000-kv-a. load per circuit
4. Voltage profiles are for outer cables on connections *B*, *E*, and *F*, and profiles are for section 1-*C*, 2-*B*, and 3-*A* for connections *C*, *D*, and *G*.
5. Impedance drops are for fault current of 3000 amperes returning over sheaths with manholes every 400 ft.

In view of this large saving, the company is trying over 90 H & M sheath bonding transformers for installation in new conduit built in 1928 where the sections of conduit are 550 to 700 feet long.

III. Sheath Voltages and Losses

The induced sheath voltages in single-conductor lead-covered cables on a-c. circuits vary logarithmically with the ratio of distance between cable centers to sheath radius, directly with the frequency and magnitude of the conductor currents, and directly with the length of section between insulating joints.

The calculated induced voltages for the 66- and 12-kv. cables of the Commonwealth Edison Company are shown in Fig. 2B. In general, for cables in contact in one duct, the voltages at rated loads are less than one volt per 100 ft., while for cables in adjacent ducts, the voltages are 1 to 5 volts per 100 ft.

At line terminals, the configuration of lengths to potheads is usually complicated and the induced voltages are affected by the locations of the busses. Because calculations are difficult and usually give results that are too low, estimates based on past experience are the most reliable guides to such cases.

If single-conductor cable sheaths are solidly bonded, the induced voltages cause currents to flow in the sheaths. Such voltages are neutralized where generated and practically no voltage will exist between the sheaths.

The sheath currents and losses are graphically shown in Fig. 2 for the 66- and 12-kv. cables of the Commonwealth Edison Company. In general, if cables are in separate ducts and sheath losses are eliminated, the carrying capacity is increased from 15 to 70 per cent, or for a given load, the copper temperature is decreased from 5 to 45 deg. cent. For cables in contact, the sheath losses, including the proximity effect, are 1 to 15 per cent of the conductor losses.

Formula and curves for determining induced sheath voltages and sheath losses with solid bonding are given in the complete paper for one circuit and for two parallel circuits having cables in various combinations.

IV. Methods of Reducing Sheath Losses

When each phase of a given three-phase line is to be carried in a separate metal-covered cable, one of the following methods might be used for materially reducing the sheath losses:

A. The sheath resistance might be greatly increased with solid bonding. The sheath loss varies approximately inversely as the resistance. However, no suitable plastic metal having a resistivity several times that of lead is known.

B. If the conductivity of the solidly bonded metal sheath is greatly increased for example by adding copper wire armoring, the sheath losses can be made less than with no armoring. This method is too expensive for any but very unusual installations.

C. If a two-conductor concentric or "D" cable is used for each phase, with the two conductors connected to opposite ends of each transformer phase winding, no sheath voltages are induced. This method is virtually six-phase and complicated and appears to have merit only for transmission of large amounts of power at low voltages.

D. Special sheath bonding connections discussed in detail below appear to be most practical for general conditions.

V. Sheath Bonding Methods

A. General Considerations. The major considerations in the selection of methods and devices for special bonding are as follows:

1. Elimination of sheath losses and increase of carrying capacity.
2. Reduction of normal induced voltages between sheaths and to ground to keep corrosion due to a-c. voltages at a minimum.
3. Limitation of abnormal sheath voltages during failures to the lowest possible values.

These objects must be accomplished without causing objectional features, such as excessive cost, interference with drainage to prevent d-c. electrolysis, or production of harmonic currents leading to telephone interference.

B. Solid Bonding. If the sheaths are solidly bonded (Fig. 2A), the installation is simple and avoids the introduction of new methods and apparatus. If the cables are in separate ducts, or farther apart, the sheath losses will cause serious reduction in carrying capacity and increase in operating cost.

C. Bonding One End Only to Auxiliary Cable. Sheath losses may be eliminated by connecting only one end of every length of sheath to some auxiliary cable (Fig. 2B) or to the sheaths of other adjacent cables. This connection requires either the use of an extra duct and a cable at considerable expense or placing dependence on other cables, which may not be permanent. One bond is more apt to become open by accident or mistake than bonds at each end and the cable sheath may be left "floating" with the possibility of acquiring dangerous potentials. The Company uses this method, however, for very irregular lengths on station properties.

D. Cross Bonding. Emanueli deviced the method where the sheaths are cross-bonded continuously along a line. (Fig. 2C). The voltages to ground are uncontrolled and may become excessive, depending upon the chance succession of unequal cable lengths. In order to avoid excessive sheath potentials, it is not desirable to confine returning failure currents to a single cable sheath for the entire distance between the failure and the line terminals, as is done in this method.

Kirke and Searing devised a method of cross-bonding (Fig. 2D) in which the cables are solidly bonded in every third manhole and transposed in the two intermediate manholes. The sheath voltages each trace the three sides of a voltage vector traingle starting at ground potential and returning to the same potential. If the cable spacing is not equilateral, or if the cable lengths are not equal, the induced voltage triangles will not close and the residual voltage is neutralized by circulating current over the three lengths. Usually the resulting sheath currents are small and the sheath losses less than two per cent as great as for solid bonding.

This method has the advantages of simplicity and

low cost, and has been used in over 90 per cent of the work of the Commonwealth Edison Company. Although insulating joints are required in two-thirds of the manholes the Company has installed them in all manholes in order that special devices could be readily installed later if the voltages to ground (which are 100 per cent of induced voltage with cross-bonding) proved too high.

E. Reactance Bonding. Emanueli and Capdeville set forth the principle of reducing potentials between sheaths and to ground 50 per cent by using impedances connected in series with the cable sheaths and by grounding the coil mid-points (Fig. 2E). The impedance of the device is made considerably higher than the impedance of the sheaths, so that little sheath current will flow and the sheath losses will be negligible. Atkinson later introduced the use of saturated iron core reactors to limit the value of sheath voltage during failures to the saturation voltage of the coils.

Although reactance coils accomplish their intended functions they introduce the following objectionable features:

1. Since they are single-phase and operate near the saturation point, triple-harmonic exciting currents are introduced into the sheath circuits, and may cause telephone interference.
2. The iron core may become saturated with d-c. flux caused by stray railway currents, thereby increasing losses and causing even harmonics in the exciting current, which may result in telephone interference.
3. During return flow of failure current along an isolated section of line, an excessive sheath potential may be caused by the addition of the reactor voltage drops (limited only by saturation) to the sheath voltage drops.

F. Resistance Bonding. Resistances may be connected as shown in Fig. 2E. They have several times the losses of equivalent reactance devices. Since they must have thermal storage to withstand failure currents of a few thousand amperes, they are relatively large and expensive. They do not have the desirable voltage limiting characteristic for minimum voltage drop during the return flow of line failure current. Finally, resistance bonding would greatly complicate protection against d-c. electrolysis.

G. Partial Current Flow Bonding. Either series resistance or reactance may be chosen of such values that any desired percentage of the sheath current with sheaths solidly bonded will be allowed to flow. In general the method is not attractive.

H. Single-Phase Transformers. Single-phase transformers have been suggested for sheath bonding (Fig. 2F). The iron core is placed either inside or outside of the joint sleeve and around the copper conductor, which acts as a one turn primary. The secondary is connected across the insulating joint to oppose the induced sheath voltage. This method has serious mechanical disadvantages and introduces practically all the disadvantages described for single-phase reactors.

I. H & M Sheath Bonding Transformers. In order to retain the advantages of 50 per cent reduction in the voltages between cable sheaths and to ground by using connection 2-*E*, or a 40 per cent reduction by using the newly devised connection 2-*G*, and at the same time not to incur the disadvantages listed for reactance or resistance bonding, the H & M three-phase sheath bonding transformer (Fig. 4) has been devised by the authors.

The normal three-phase reactance of the primary coils is high, only a small exciting current flows, and losses are negligible. The secondary coils function normally only as a tertiary winding preventing the flow of triple harmonic currents in the sheaths. During a failure, the single-phase failure current returns nearly equally divided on the three cable sheaths and in parallel through the three primary coils. Because of the secondary winding, the device then behaves exactly as a short-circuited transformer and the series reactance of the transformer is due to leakage flux only (not

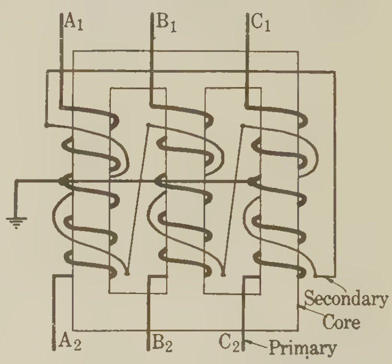

Fig. 4—Wiring Diagram of Three-Phase H & M Sheath-Bonding Transformer

Series primary-wound secondary type for use in connection *E* of Fig. 2

saturation flux) with the result that the reactance drop is minimum in value.

As the stray direct currents flowing in the three sheaths and coils will be practically equal, the d-c. flux must return through an air path; hence, these stray currents will have no undesirable effect on the a-c. characteristics of the transformers. Since the transformer coils present very small resistance to the flow of direct current, they will introduce no complications into d-c. electrolysis mitigation. The three-phase transformer allows large economies in size, weight, and convenience of installation.

In the scheme of connections (Fig. 2G) devised by the authors, the cable sheaths are cross-bonded continuously throughout a line, with the center of the vector triangle of sheath voltages grounded by star-connected transformers spaced at every second manhole. Under practical conditions, the sheath voltages to ground are reduced about 40 per cent by this connection. For this connection, there is a saving in investment cost, since only half as many coils are required, and since the coils may be wound for about 60

per cent as much voltage as for the series connection.

J. General Comparison. In order to make a general comparison of the various schemes, Fig. 2 has been prepared. The profiles apply only to the normal voltage on the cable sheath. The maximum voltages occur in all cases in the manholes where the insulating sleeves are installed. Also there are shown sheath currents and voltages for normal operation and sheath voltage drops for failure currents.

Voltage tests have been made on all 12- and 66-kv. single-conductor cables bonded for the elimination of sheath losses, and on several short sections of line specially bonded for tests. In all cases the measured sheath voltages check those calculated by the ordinary logarithmic formulas within 10 per cent. No measureable difference in sheath voltages was obtained for any of the connections with the cables dry or submerged in water. Tests have been made on connections *A, B, D, E,* and *G* of Fig. 2 and on some other less promising connections not shown. Tests were made using single-phase Atkinson saturated core reactors and H & M three-phase sheath bonding transformers, both devices being rated at 22 volts per phase. The test voltages for all cases confirmed the theoretical values.

FIG. 5—H & M THREE-PHASE SHEATH-BONDING TRANSFORMER

Bar secondary type—(cover removed)
Case is normally filled with a hard compound

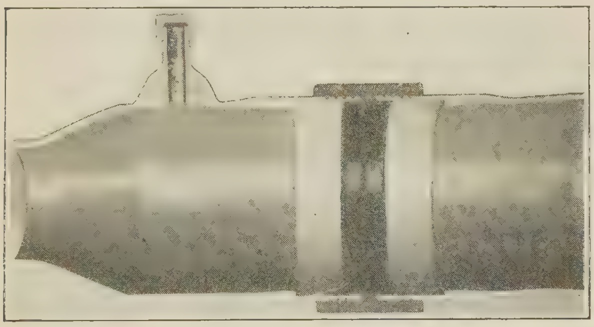

FIG. 7—CROSS-SECTION OF ONE-HALF OF 66-KV. JOINT SLEEVE WITH H & T INSULATING SLEEVE

VI. INSULATING JOINTS

In any method of reducing sheath losses by special bonding, insulating joints are required. Several designs using different methods of construction are now on the market.

The H & T insulating sleeve has been used for almost all of the work of the Commonwealth Edison Company. Fig. 7 shows one of its applications. No leaks have occurred in these insulating sleeves in service, and several which had operated for over two years under water with 15 to 35 volts across the Bakelite were inspected and all found to be in good condition.

When a common oil reservoir is used for all three joints, insulators must be used in each of the three oil pipe lines. Suitable insulators are available.

VII. A-C. ELECTROLYSIS

The principal problem introduced by a-c. sheath voltages is the production or increase of sheath corrosion. The extensive laboratory and field tests of the Commonwealth Edison Company indicate the principal factors to be as follows:

a. Current density, which is dependent on the sheath voltages and on the resistivity of the surrounding manhole water, conduit, and fireproofing.
b. The chemical nature of the water, ducts, and fireproofing.
c. Superimposed d-c. potentials.
d. Temperature.

For the concrete conduit with precast concrete ("stone") ducts and for the rope and cement fireproofing (with and without asbestos tape next to the load sheath) the range of resistances found was as follows:

RESISTANCE TO GROUND PER FT. OF CABLE* SHEATH—OHMS

	Max.	Min.	Ave.
Bare cable sheath in manhole water........	35	1.5	10
Wet fireproofing on cable..................	100	10	50
Cable sheath in submerged ducts..........	1500	250	400

*Over-all diameter — 2.8 in.

Tests showed that the resistivities decreased about 15 per cent if the temperature was increased for 15 to 25 deg. cent. and 50 per cent for a change from 10 to 40 deg. cent. The increase of corrosion with temperature which was found appears to be due to stimulation of chemical activity as well as to an increase of current density.

Hayden[3] found that a-c. electrolysis could be greatly reduced or even removed by superimposing a negative d-c. voltage about 1½ per cent of the a-c. voltage. Tests made in Chicago indicate the converse is true and that precaution is necessary to prevent the sheaths from becoming positive to earth if a-c. sheath voltages are present.

Secondary chemical reactions which are very difficult to analyze or predict appear to be chiefly responsible for the corrosive effects of a-c. voltages. So called self-corrosion which may be caused by chemicals from the surrounding soil or conduit structure, by differential galvanic action, or by impurities in the

3. *A-C. Electrolysis*, J. L. R. Hayden, TRANS. A. I. E. E., 1907, Vol. XXVI, p. 201.

lead, may be stimulated by a-c. potentials. Pitting is the most serious result and cannot be properly evaluated by weighing tests.

From two years of laboratory tests and field experience, it appears that for cables submerged in water an a-c. potential of 12 volts between sheath and ground is a practical safe limit for Chicago.

Similar corrosion problems may be encountered when lead-covered cables with or without a fibrous covering are buried in the earth. The various methods for reducing sheath losses and possible corrosion described in this article for cables in ducts are equally applicable to buried cables.

VIII. Conclusions

1. For cables separated as in ducts the elimination of sheath losses results in increased load ratings of 15 to 70 per cent and in decreased total cable losses of 20 to 75 per cent.

2. Experiments have verified the calculated sheath voltages for the various bonding connections.

3. If sheath voltages on regular sections of cable must be reduced because of corrosion due to a-c. electrolysis, it appears very desirable to use the bonding connections shown in Fig. 2E or 2G for which the three-phase sheath bonding transformer seems most suitable.

4. Satisfactory insulating joints are essential for the practical elimination of sheath losses and successful designs are available.

5. Alternating current electrolysis is a complicated phenomenon and few definite conclusions can be drawn. Field tests and experience in Chicago indicate that 12 volts to ground is a practical safe limit.

Acknowledgment

The authors wish to express their appreciation of the very helpful assistance given by Messrs. D. W. Roper, Karl Horine and their assistants in obtaining the field and laboratory data.

Forces on Magnetically Shielded Conductors

BY J. H. MORECROFT[1] and ALVA TURNER

Fellow, A. I. E. E. Non-Member

Synopsis.—The results of some simple experiments are given to show how the magntic force, acting upon a current-carrying conductor in a magnetic field, is affected as the conductor is shielded by surrounding it by a permeable shield. It is shown that the force on the conductor practically disappears if it is put inside of an iron pipe, but that the pipe experiences a force—the sum of the force in the pipe and that in the conductor being the same as that in the unshielded conductor.

The idea is extended to the conductors in a slotted armature. It is shown that as the conductor is placed more deeply in the slot the force diminishes to a minimum and then experiences a slight rise at the bottom of the slot.

The ordinary electric motor develops torque because of the interaction of the flux from the field poles and the current-carrying conductors in its armature. These conductors are generally imbedded in slots. An interesting question, the answer to which is not apparent is,—Do the conductors themselves develop the turning effort of the armature and then transmit it to the shaft by pressing on the sides of the slots, or is the force developed directly in the iron core of the armature? An argument at the lunch table furnished the basis for the following simple experiments.

A rigid conductor was suspended in an adjustable transverse field and current passed through it; the mechanical force tending to push the conductor across the field was measured. The conductor was then threaded through an iron pipe, with a bore large enough to be held free from the conductor. The pipe was of sufficient length to extend beyond the edges of the magnetic field in which the conductor was lying. In this way the conductor, through practically all of its active length, was shielded from the magnetic field.

The force was again measured and found to have only a small fraction of the value it possessed when no pipe surrounded the conductor; evidently the pipe furnishes such a low reluctance for the flux that practically none appears inside the pipe where the conductor is lying. That some force appears is due to the imperfect shielding of the pipe, its length being insufficient to eliminate completely the effect of the field fringe, and probably due to that part of the field of the conductor which lies outside the pipe.

While shielding the conductor from the outside field, the iron pipe does not in any way affect the strength of field set up by the current in the conductor at points outside the pipe; that is, if the conductor, carrying a certain current and giving a field of 100 gauss at a point 5 cm. distant from the conductor when no pipe is used, is surrounded by a thick iron pipe of 8-cm. outside diameter (so that the point 5 cm. distant lies outside the pipe), the flux density at the 5-cm. point will still be 100 gauss. And of course the same statements holds good for points between the conductor and the inner surface of the pipe. In so far as the magnetic field of the conductor is concerned the iron pipe has no effect on its strength except inside the material of the pipe; here the flux density is increased by an amount proportional to the permeability of the iron.

With the conductor inside the pipe, it developed but little force in our experiment, but the question arises—How about a force on the pipe? Does this experience a force tending to make it move transversely in the field?

The apparatus was arranged as indicated in Fig. 1

1. Prof. of Elec. Engg., Columbia University.

Printed complete in this issue.

which gives a view looking at the end of the conductor. N and S are the poles of a powerful electromagnet, having an air-gap about 6 in. long. The conductor was supported centrally in the field, knife-edge supports and a calibrated spring permitting us to measure the downward force when current was passed through the conductor.

The pipe was held in a bridle which prevented it

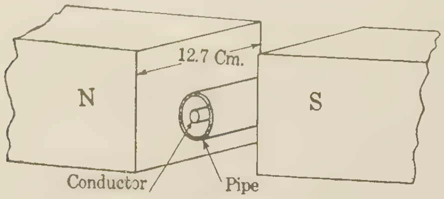

Fig. 1

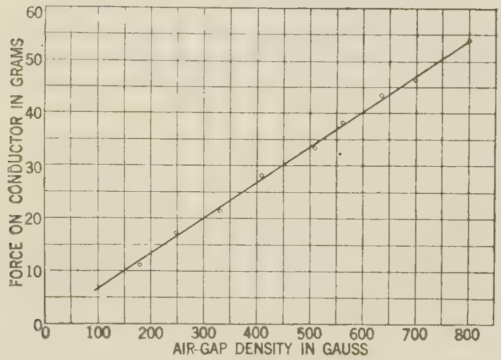

Fig. 2—Force on Unshielded Conductor

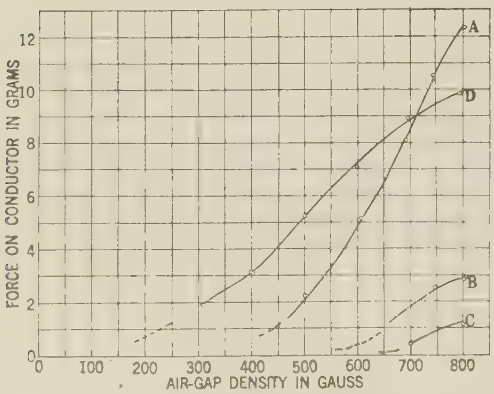

Fig. 3—Force on Unshielded Conductor

Sizes of pipe used for shielded:

Inside diameter	Wall
A—2.20 cm.	0.080 cm.
B—2.06 cm.	0.318 cm.
C—2.70 cm.	0.318 cm.
D—1.11 cm.	0.318 cm.

moving parallel to the field of the magnet, but permitted the measuring of the force tending to move it up or down across the field.

The results given on the curve sheet must be regarded as qualitative only, as we did not know the magnetic characteristic of the ion used in the pipes, and made no corrections for change in the reluctance of the magnetic circuit, as different pipes were used.

Fig. 2 shows the force in grams acting upon the unshielded conductor, as the current through it was held

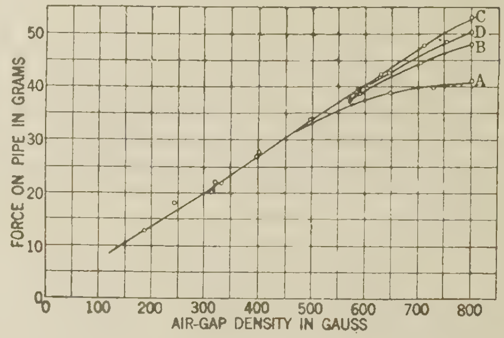

Fig. 4—Transverse Force on Pipes Specified in Fig. 3

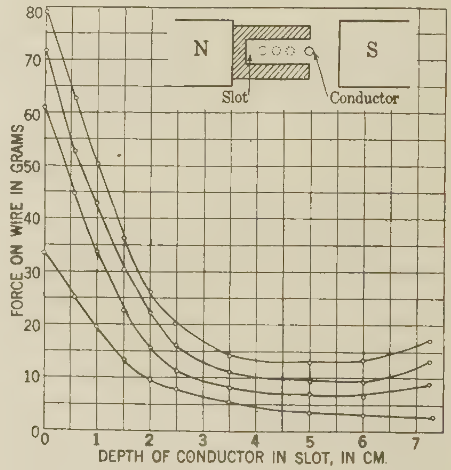

Fig. 5—Force on Conductor in Slot

Current in conductor—25 amperes
Dimensions of slot—2.7 cm. by 7.45 cm.
Field current:
Curve A—1 ampere
B—2 ampere
C—3 ampere
D—4 ampere

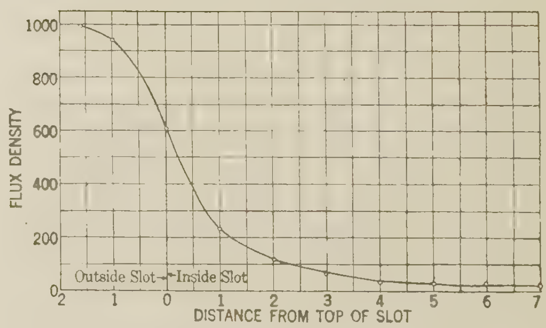

Fig. 6—Flux Density on Center Line of Slot

Field current—1 ampere

constant at 25 amperes and the density of the field of the electromagnet was changed from 180 to 800 gauss.

The conductor was then enclosed in a pipe having an inner diameter of 2.22 cm. and wall thickness of 0.80 mm. The current was again held at 25 amperes and

the force in the conductor was measured, giving the curve marked *A* in Fig. 3. Evidently the pipe cuts down the force in the conductor to about ¼ its value with no enclosing pipe.

Three other pipes were tried, *B* having inner diameter of 2.06 cm. and wall of 3.18 mm.; *C* having 2.70 cm. inner diameter and 3.18 mm. wall; and *D* having 1.11 cm. inner diameter and 3.18 mm. wall. The force for each case was measured and is given in Fig. 3. Evidently pipe *A*, with its thin wall, tends to saturate at the higher field strengths; this decreases its shielding action and results in greater force in the conductor.

In Fig. 4 are shown the curves for transverse forces acting on the different pipes, the conductor inside the pipe carrying 25 amperes. There is an evident tendency for pipe *A* to reach saturation,—and even the other pipes show the effect to some extent.

If the force on the conductor itself inside the pipe is now added to the force on the pipe, the sum gives a total force just the same as that given by the conductor itself, unshielded. The shielding, therefore, simply transfers the force from the conductor itself to the shielding material.

An experiment was arranged to measure the force on conductors strictly as they are used in armatures; Fig. 5 shows the apparatus used. An iron "slot" was built up, having about the dimensions of the slot of an actual armature. The conductor was then placed at different positions in the slot and its force again measured, the current in the conductor being 25 amperes, as it was for all the other curves. The curves given in Fig. 5 show at once that the mechanical forces in the conductors in the bottom of the slots of a machine are almost negligible compared to those for the top conductors.

In Fig. 6 is shown the experimentally determined flux density throughout the depth of the slot (with one ampere in the field), and the conductor forces are proportional to these densities.

Therefore the conclusion is reached that each conductor on the armatures of a motor contributes the same turning effort to the shaft; however, the conductors in the lower part of the slot give their force directly on the armature core while those near the top of the slot deliver their force through the compression of their insulating covering.

Insulation

The Opportunity for Research

BY J. B. WHITEHEAD*

Fellow, A. I E. E.

CONSIDERING the wide range of types of electric circuit, it is at once evident that an equally wide variety of properties,—electrical, mechanical, and thermal,—is demanded for their insulation. Experiment and research directed toward improvements in insulation, therefore, have an almost unlimited field of opportunity. An enormous mass of experimental data from experienced investigators has already been presented. So wide is the problem, however, that these data have not only failed to place the design of insulation on a satisfactory engineering basis, but still leave it as probably the most important problem confronting the electrical engineer of today. The life of electric equipment is often limiten to that of its insulation, and the consequences of failure are usually disastrous and costly.

In large measure, insulation as we have it today is the result of empirical and cut-and-try methods rather than based on fundamental knowledge. Manufacturers and engineers have made a splendid record of discovery and improvement. There is, however, little of law, order, and fundamental knowledge as guide posts for further progress. Indeed, we may say that only a few general principles have been discovered, such as the importance of the elimination of air and moisture and the limitation of high temperature. Beyond this, we have only the results of the patient purification and selection of materials, as related to special forms of insulation and manufacturing processes. In many cases, the control of materials as regards uniformity of product is still wanting, and close engineering design is still in the remote future. Liberal factors of safety are necessary to cover the ever present weak spot, thus increasing material, filling valuable space, and adding weight, size, and cost.

What is the explanation? We know very little as to the nature of the fundamental properties of dielectrics. The perfect dielectric as conceived by Faraday does not exist. We can improve the dielectric properties of many materials, and we have even invented new compounds with desirable thermal, electrical, and mechanical advantages; but all in their best forms still have electrical conductivity, dielectric absorption and loss, and show more or less rapid deterioration under electric stress. In spite of the splendid record of manufacturers and engineers in the improvement and control of dielectric materials, it is increasingly evident that the possibilities of the empirical study of these materials are about exhausted, and that further advances can come

*Address of the Chairman to the Committee on Electrical Insulation, National Research Council, Johns Hopkins Univ., November 17, 1928.

only from a more intimate knowledge of those underlying and ever-active phenomena associated with a state of electric stress in a dielectric.

The situation thus appears to offer fine opportunity to the pure research worker. Little is known of these fundamental processes, and the rewards of deeper knowledge leading to thei· control would be very great. On the other hand, the experimental difficulties are enormous. In fact there is probably no field in which the control of the conditions of experiment is more difficult, and the interpretation o observation more liable to error. A survey in any aspect of the great mass of data already acquired yields so little definiteness of result and presents so many apparent inconsistencies, that coordination aiming at even empirical laws is clearly impossible. Physicists have attempted to explain the conductivity of liquid dielectrics in terms of the more firmly established laws of gases. The results are not impressive and the problem of solids is scarcely approached. Moreover, the refinement of method necessary to these studies, in itself indicates a different type of problem from those confronting us in electrical insulation. Extreme processes of purification, refinement, and the conservation of these properties, impose great difficulties and expense in the handling of large quantities of materials under ordinary manufacturing methods.

It might almost be said that the present problem in dielectric research is a further knowledge of the fundamental laws of materials in a *partially* pure state; quantitative data as to the effect of different amounts of impurities most difficult to eliminate; the influences most active in the progressive changes in the properties of dielectrics; and the nature of the electric carriers involved in the conductivity of liquids, oils, greases, and composite solids, under conditions of relative purity attainable by the best manufacturing processes.

The aim of this paper is to make a few definite suggestions of present problems for research; in fact to propose a program under which various experimenters may work under a coordinated plan, with mutual support and the avoidance of duplication of effort. Since the field is so large, the scope of the suggestions has been limited to some of the more conspicuous aspects of the general problem.

High-Voltage Insulation

There are few more important problems than those involved in the insulation for high-voltage circuits. All dielectric processes are intensified at high stress. Moreover, those properties of high-voltage insulation which apparently lead to its limitations,—namely, conductivity, absorption, and loss,—also play dominating parts in many types of insulation for lower voltages, such as all forms of communication and radio equipment. Therefore, by their nature studies in the high-voltage field will throw light on the many other classes of problem.

Probably the two most important characteristics of high-voltage insulation are high electric strength and long life; *i. e.*, slow deterioration. On neither of these properties is there any sound fundamental knowledge, either as to their ultimate nature or their predetermination and control in composite materials. The last ten years, however, have produced some very remarkable results as to the general character of the underlying processes which offer great promise of reward for further careful experiment.

Dielectric Strength

The confusion of data on the dielectric strength of solid materials is well known. Such simple questions as the changes of dielectric strength with thickness and temperature show wide variation not only among different experimenters, but in the results of single workers. The last ten years have seen a remarkable series of investigations on this subject by such workers as Günther-Schultz, Wagner, Gruenwald, Dreyfus, Gabler, Rochow, Mundel, Rogowski, Smekel, Joffé, Böning and others. The results indicate clearly that direct experiments on breakdown strength, even under conditions most carefully controlled, cannot of themselves lead us to a knowledge of the nature of the underlying processes. The confusion and variations of data show that the controlling causes lie deeper, involving the type and mode of motion of electric charges through the molecular cage work constituting the structure of the dielectric.

There is some suggestion that this recent outpouring of important work on dielectric strength was precipated by the so-called pyroelectric theory of Wagner, although engineers had long before recognized the hot spot in insulation as the forerunner of breakdown. Wagner's proposal was so sketchy,—so faulty in its assumptions,—that it at once led to sharp criticism and to a more careful analysis of conditions surrounding temperature rise within the mass of a dielectric. Supplemented by the more careful analyses of Dreyfus, Rochow, Gabler and others, it became immediately evident that this proposal goes no further than to point out the influence of temperature elevation on breakdown strength, and says nothing as to the nature of the ultimate process of breakdown.

Making use of the results of the X-ray analysis of crystals, Schmidt, Smekal, and Rogowski have made very important studies of the relation between the theoretical breakdown strength of solids and those as observed in experiment. Until this work, discrepancies between these two figures, have been of the order of 20 to 100 times. On the assumption of a loose or porous composition and the presence of cleavages in crystals whose patterns are known, Rogowski has shown that under the laws of gases, the motion of ions in an electric field may be sufficient to upset the temperature equilibrium of a crystal, leading to secondary ionization and progressive breakdown at values of electric stress corresponding to those of practise. The presence of these microscopic cleavages in crystals

has also been definitely shown by other methods, with evidence as to their approximate dimensions. Proceeding in a somewhat different manner, Böning proposes a theory of breakdown of other forms of solids, such as due to the accumulation of space charge, and local high stress owing to a conductivity of electrolytic character. He thus utilizes conditions more nearly simulating those obtaining in the insulation of practise. Similarly, Günther-Schultz proposes a theory of breakdown of liquid dielectrics, which, in effect, proposes the acceleration of a free moving ion, leading to temperature elevation sufficient to create a gaseous space, and thus giving opportunity for the movement of more powerful gaseous ions leading to cumulative secondary ionization.

The outstanding feature in all the work thus briefly outlined is the increasing attention focused on the motion of ions as the underlying cause of breakdown. No dielectric is free of conductivity. Conductivity means the motion of ions, and consequently every dielectric has already within it the potential causes of breakdown. Obviously conductivity may be present without the possibility of secondary ionization, or at least the latter may be in such small amounts as to be limited in the area of its influence. It is easy to see, however, that even if breakdown is not imminent, local conductivity may lead to local changes, both physical and chemical, in the structure of the dielectric, with increased conductivity, increased dielectric loss, more rapid deterioration, and shorter life.

Simple methods for studying these recent theories of the mechanism of breakdown do not suggest themselves immediately. A proper study of Rogowski's suggestion would involve various forms of a crystal lattice pattern, in relation to submicroscopic fissures of different dimensions. It might be possible to determine the relation between internal gas space, molecular structure, and dielectric strength, but the difficulties would be great. In the case of liquids, the suggestion of Günther-Schultz should be susceptible of test. If the suggestion is correct, variations in breakdown strength should be found among liquids having different vapor pressures and when subjected to radio-active or other influence stimulating the production of ions, or bearing on the process of gaseous ionization.

As suggested above, however, the breakdowns of practise are the culmination of processes of disintegration and deterioration of the insulating material. For the present, at least, the control of these processes is more important than a knowledge of the final mechanism of breakdown, interesting of itself though that may be. They are in all probability due to the joint influence of electric stress, the original chemical structure of the material, and small amounts of impurities never completely eliminated. Dissociation, conduction, electrolytic action are insidious and cumulative sappers of the structure of any dielectric. Thus, the problem of dielectric strength, in the light of present knowledge, is the preservation of an original value, rather than a search for higher values, and so merges itself into that other important property of insulation—long life.

Dielectric Loss and Life

Progressive deterioration under sustained electric stress is one of the commonest troubles of electrical insulation. These changes invariably mark the steps toward ultimate failure. They are usually accompanied by corresponding increases in dielectric loss. As a consequence, much experimental study has been devoted to the laws governing dielectric loss. These studies have resulted in a fair understanding of the variations of loss with voltage, frequency, temperature, etc., under otherwise constant conditions. They tell us nothing, however, of the ultimate nature of the loss, nor of the underlying processes of change.

A more promising avenue of attack appears to lie in the phenomenon of dielectric absorption between which and dielectric loss a very close correlation exists, as based both on experiment and on theory. The nature of the phenomenon of residual charge or absorption is not understood. Maxwell's theory is inadequate and no other completely satisfactory explanation has been proposed. Probably there are several possible causes, but the most promising appears to be a retarded motion of electrolytic or other type of ion accumulating as space charge near the electrodes. Anderson and Keane have reported a brief analysis of this idea, showing that the variations in ionic density necessary to account for absorption as observed are not very great. This effect has been noted by Warburg and others for liquids, and by Joffé for certain crystals. There are few data on the various solid composite materials so interesting from the standpoint of electrical insulation. From this point of view, absorption arises in conductivity which takes on a distinctly anomalous character in most dielectrics. Another view is that absorption or residual charge is due to a slow polarization of the dielectric, the conductivity at all times having a definite value. This view is an old one, supported by the work of J. Curie, and latterly has been emphasized by Joffé and his co-workers. The proposal affords excellent opportunity for experimental test.

Both absorption and anomalous conduction are easily studied, and it would appear that we have here an interesting and promising field not only for uncovering some of those processes involved in the progressive deterioration of dielectrics and insulation, but also for further knowledge of the nature of the phenomena themselves.

Research in this field would therefore naturally take the direction of further studies of the causes of dielectric absorption, with particular reference to the movement of ions and electric charges inside the body of the dielectric. These are not easy problems, but among other methods of attack may be suggested studies in the variation of potential gradient of dielectrics under stress and the possible non-uniform occurrence of space charge.

The presence of a definite polarization e. m. f., as suggested by Curie, Joffé, and Euguchi, and the location or nature of its origin, seems an especially promising line of attack. Research should take the direction of studies of the variations of this phenomenon with temperature, viscosity, and with added impurities, such as air and water, and particularly with variations of chemical composition. This would be especially important, not only in its fundamental character, as bearing on theory, but also from the standpoint of improvement in the insulation of practise.

The use of impregnated paper for high voltage insulation gives this material a special interest. It possesses dielectric absorption which has not been completely studied. Many problems are therefore suggested. Data are wanted as to the relative importance of the paper and the compound in determining the final absorption and loss, together with their variations as related to voltage and temperature. The separate origin of the reversible and irreversible components of the absorption current should be traced. The variations of these quantities with sustained electric stress should be studied for both continuous and alternating stress, and methods should be developed for studying their influence on oxidation, electrolytic action, polymerization, redistribution of material, variation in potential gradient, and the presence of space charge; the mutual influence of paper density, moisture content, and power-factor—voltage relations; the influence of pressure on conductivity and on gaseous ionization in impregnated paper. A pressing question at this time is whether the increasing loss and deterioration of impregnated paper insulation is due to the decomposition or polymerization products themselves, or to a condition, such as the presence of free ions, arising in the process of chemical change.

Insulating Liquids

The early work of Warburg, and since his time of others, has indicated that the conductivity of liquid dielectrics often shows evidence of pure electrolytic character. Others, such as Schröder, Schering, Mie, Jaffe, Van Der Beijl, have studied the character of the free ions occurring in poorly conducting liquids, and have attempted to explain the phenomenon of conductivity in liquid dielectrics in terms of the more definite laws governing conduction in gases. In general, however, liquid dielectrics, even when carefully prepared, must be considered to have a very complex character, possessing to some extent not only electrolytic conduction, but also containing other types of ions possessing a wide range of mobility, and which are usually attributed to the presence in dissociated forms of other materials, such as, for example, water.

The purpose of the physical research, thus briefly described, is directed toward the basic nature of the processes involved. Little has been done in orderly method toward linking up these fundamental researches with the properties of liquid dielectrics, such as used for the electric insulation of engineering application. Little or no reference is found, for example, to an initial high value of charging current, decreasing rapidly with time after the application of voltage, similar to the absorption current in a solid dielectric. Such currents are known to occur in liquids, and the theories proposed do not clearly account for them. It has been stated that liquid dielectrics show no residual charge and that the principle of superposition does not apply. This statement needs further supporting evidence, particularly in the case of commercial insulation. The work of Tank, Joffé, and of Sinjelnikoff and Walther has indicated that certain liquid dielectrics have for a given stress an initial limited maximum value of charging current, which decreases more or less rapidly and they have attempted to link this value with the electric loss under alternating stress. Variations of conductivity or current during extremely short intervals of time following variations of electric stress, constitute the most important factor bearing on dielectric loss, power factor, phase difference, etc., and in all probability on the permanence of the structure of the insulation.

Obviously the liquids offer the best opportunity for the study of the motion of ions. As already indicated much work has been done in this direction on very pure liquids. We now need information as to the changes in the mass, mobility, and other properties of these ions, with increasing amounts of original impurities. Such data paralleled with short time measurements on charge and discharge currents, and on alternating loss, should go far toward indicating a method for the selection of liquids of greatest stability and longest life. Other promising problems are the relative power of various types of ionizing influence, X-rays and other electromagnetic radiation; oils, for example, deteriorate under light. Space charge, absorption, and perhaps polarization are readily observed in liquids; studied in relation to temperature and to electric stress for both long and short time intervals they should yield important fundamental knowledge.

A Suggestion for Progress

If the point of view of the foregoing paragraphs is correct it would appear that an essential feature of future research in electrical insulation should be the study of the size, motion, and other characteristics of mobile ions, their accumulation as space charges, and their relation to the chemical constitution, origin, and subsequent states of the dielectric material. There will be other important problems but those of the type mentioned must be attacked if further fundamental knowledge is to be our aim.

The suggestions for experiment under the several foregoing headings have been quite general, but they may readily be expanded into a list of specific problems. It will be found at nearly every point, however, that the method and technique of the more desirable ex-

periments require a skill and experience usually possessed only by those trained in pure research in the fields of physics and chemistry, as well as in electrical engineering. This is a combination that is somewhat rare, and in considering any plan whereby coordinate research may be prosecuted in the field of insulation, it is seen at once that the question of personnel is one of the most serious difficulties. As in so many other aspects of the applications of electric science, the question of further progress depends more and more on the discoveries of the pure scientist, so now in particular, in the question of insulation, it is evident that we must live more and more closely in contact with the current progress in the field of pure physics. A combined physicist, chemist, and engineer obviously offers the best chance for rapid progress. Failing this combination in one man, collaboration between electrical engineer and physicist offers the next best promise. Here, however, is another difficulty, for in recent years the physicist has not been attracted by the problems of dielectrics and insulation. From the literature one receives the impression that the physicist attributes the anomalies of insulation to the presence of impurities, and that this being the case dielectric absorption is still to be explained by Maxwell's theory, and that if it were possible to secure substances sufficiently pure they would possess the characteristics of Faraday's original conception.

Pure physical research in the field of dielectrics seems to be limited at the present time to studies of specific inductive capacity in its relation to modern theories of the nature of the structure of the atom. One phase of this work explains specific inductive capacity in terms of the shifting of electron orbits within the atom. Another phase, due to Debye and his followers, finds that the specific inductive capacity, or a part of it, arises in an inherent dissymmetry of the arrangement of electrons and positive charges in molecules, resulting in a definite polarity of the latter, thus forming a so-called electric di-pole. The electrets of Euguchi, showing a permanent electrification similar to permanent magnetism, fall into this class. Important and stimulating as these discoveries and theories are in their extension of our knowledge of the nature of the ultimate structure of matter, they as yet throw little light on the phenomena arising in the dielectrics which must be used for insulating purposes. For example, none of them makes suggestion of the nature of dielectric absorption and loss. There is no doubt, however, that those physicists who have been drawn to the problem of the dielectric atom would in all probability be attracted by that of dielectric loss, if its magnitude and importance could properly be brought before them. It becomes the duty, therefore, of the research engineer to seek out those physicists and chemists working in the field of dielectrics and to stimulate their interest by setting forth the importance of our problems and the insufficiency of present physical theories to account for them. This, next to the continued prosecution of our program of direct attack, I regard as the most important opportunity of the committee.

The foregoing outline of the problem of insulation, and the opportunity offered for research, has been brought together as the result of an effort, as Chairman of the Committee on Electrical Insulation of the National Research Council, to prepare a list of specific problems for experimental attack, and a plan for its general prosecution in various research laboratories, as far as possible under coordinated control for mutual aid and the avoidance of the duplication of effort. The committee invites the participation of all research workers interested in this field. It will gladly submit the list of its problems and give information as to work already under way. It is also in position to suggest possible sources of financial support for problems in its program when there is good promise of capable and active prosecution.

LOOKING BACKWARD

Today it is apparently permitted that one take an occasional glance at the things that have been left behind in the climb up from the past without suffering the penalties imposed upon the ancients. Pillars of salt have given way to a show of reason. Foresight, is, however, denied to an amazing degree.

Several weeks ago we commented upon the progress in radio communication and the legal penalties imposed upon some far-sighted promoters and engineers. A recent issue of *Coal Trade* throws an interesting backward glance at a comment of fifty years ago. In a report upon contemporary trade conditions in its issue of October 30, 1878, it was stated:

"Anthracite sales are booming. Bituminous-coal dealers also are reporting satisfactory business. Gas coals are without any special movement as the season is nearly over. Mr. Watkins, president of the Chicago Gas Light & Coke Company, 'does not anticipate any shrinkage in the profits of his company by reason of Edison's alleged discovery of a means to economically utilize electric light.' He says that he has carefully watched the operations of this noted inventor and is unable to see that a method has been established which will furnish light to a large number of consumers at a rate that will enter into any active competition with gas."

One may blush for Mr. Watkins, or his shade, but the same thing is being done today. Who will believe that newspapers will soon be a thing of the past, their place being taken by synchronized television and radio in every home? Who is rash enough to foresee that cities will be no more—since speedy transportation may place us all within minutes of wherever we may desire to go? Who concedes even the remote possibility of a development that will render generating stations and transmission lines useless except as museum pieces? Who dares—yet inevitable change is waiting just around the corner. Today's certainties are tomorrow's amusing, long-dead jests.—*Electrical World.*

Abridgment of

A-C. Elevator Motors of the Squirrel-Cage Type

BY E. E. DREESE[1]
Member, A. I. E. E.

Synopsis.—This paper sets forth the features of squirrel-cage motor design which differentiate it from standard motors. Much of the paper is devoted to the two-speed motor with two separate stator windings having speed ratios of 2/1, 3/1, 4/1 and 6/1. The two-speed motor with a single winding is limited to the 2/1 ratio. Higher ratios are necessary for high elevator speed and low and accurate landing speed.

The elevator motor is subjected to continual starting and stopping. The effects of inertia in such service are considered in connection with motor heating.

The proper division of slot area between the two stator windings and the problem of building a rotor with proper characteristics on both speeds are explained.

Noise elimination is necessary in elevator motors. The effect of this requirement in design is considered.

The effect of rotor skew is compared to the effect of distributed winding in the stator. The quantitative effect of skew is embodied in a constant called "skew factor."

The possibility of transformer effects between the windings of a two-speed motor is explained and methods of correcting to eliminate circulating currents are indicated.

* * * * *

THE induction motor as developed for elevator drive is a highly specialized type of machine. Slip-ring motors have been used, but the complications of control and the difficulty in eliminating noise have caused them to give way to the high-resistance squirrel-cage type. The high-resistance rotor can be designed to give the maximum torque when starting and the torque per ampere is high. Another advantage of the high-resistance rotor is that it reduces the stator heating during a change of speed.

For a low-speed elevator the stator is usually wound for a single speed. For higher speeds the motor is

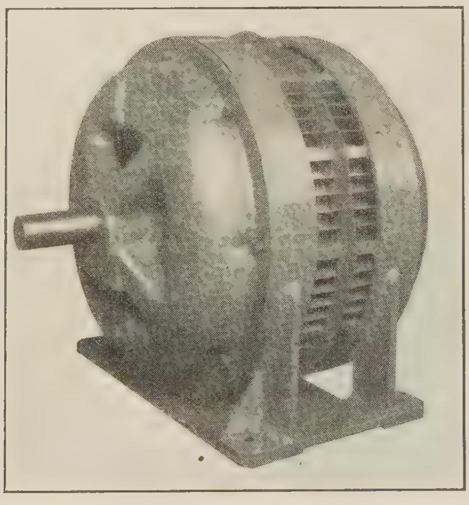

Fig. 1—Squirrel-Cage Type Elevator Motor

built for two speeds since at high elevator speeds it is more difficult to make accurate landing. In the case of two-speed motors, the high-speed winding is generally used for starting and running and the low-speed for retarding and landing. The speed ratio required for the two windings should be greater the higher the speed of the elevator. Common speed ratios are 2-1, 3-1, 4-1, and 6-1. The high speed usually has four poles or more and the low speed 48 poles or less. The speed-torque and current-torque curves of a representative motor are shown in Fig. 2.

Inertia Loads

In order to understand the design problems in this motor, it is necessary to grasp the fundamental ideas

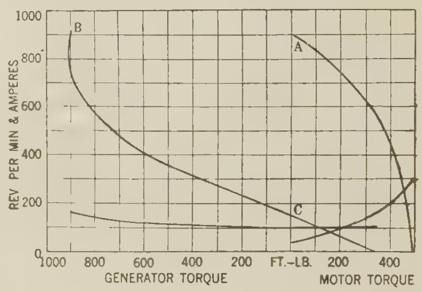

Fig. 2—Torque and Current Characteristics of 6-1 Elevator Motor

of the type of load the motor is required to handle. Consider the simple mechanical arrangement consisting of a motor driving a drum over which is hung a cable carrying an elevator cage on one end and a counterweight on the other. The counterweight is usually enough to counterbalance the weight of the cage and a certain portion of the capacity load. The energy relations involved in the accelerating and retarding of an induction motor with a pure inertia load are easily derived.

The mechanical power output of the rotor is given by

$$\text{mechanical power output} = K\,\omega\,T$$

where ω and T are the angular velocity and the torque respectively and K is a constant depending upon the system of units. From elementary induction-motor theory the electrical power input to the rotor is given by

$$\text{Electrical power input} = K\,\Omega\,T$$

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Presented at Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

Where Ω is the angular velocity at synchronous speed. Since the load is inertia only

$$T = \frac{I}{g} \frac{d\,\omega}{d\,t}$$

Where I is the *equivalent* moment of inertia of the rotor and is determined by transferring all of the kinetic energy of the moving parts of both motor and connected load to the rotor. The *energy* relations for the rotor during change of speed may then be set up as

$$\text{Mechanical energy output} = \frac{K\,I}{g} \int_{t_1}^{t_2} \omega \frac{d\,\omega}{d\,t}\, d\,t$$

$$= \frac{K\,I}{2\,g} (\omega_2^2 - \omega_1^2) \qquad (1)$$

$$\text{Electrical energy input} = \frac{K\,I\,\Omega}{g} \int_{t_1}^{t_2} \frac{d\,\omega}{d\,t}\, d\,t$$

$$= \frac{K\,I\,\Omega}{g} (\omega_2 - \omega_1) \qquad (2)$$

The expression (1) simply states that the mechanical output of the rotor during change of speed is equal to the change of kinetic energy. The above expressions are general. Their significance will become clear if certain special cases are considered.

Rotor Efficiency During Acceleration

If an induction motor comes up to synchronous speed from standstill

$$\omega_1 = 0 \qquad \omega_2 = \Omega$$

$$\text{In this case rotor output} = \frac{K\,I\,\Omega^2}{2\,g} \qquad (3)$$

$$\text{rotor input} = \frac{K\,I\,\Omega^2}{g} \qquad (4)$$

It is thus seen that

Rotor loss = kinetic energy

This relation is true whatever the rotor or stator resistance and whatever the flux density. Indeed all of these quantities may be variables during the process of acceleration.

Rotor Efficiency During Retardation

In elevator operation the process of retardation from high speed consists of throwing over to the low-speed winding. Reference to the curve in Fig. 2 will show the situation. With the high speed in operation the elevator with pure inertia load is operating at point A. After the shift to low speed it is operating at B and the rotor is subjected to retarding torque. The rotor is retarded until it is in low-speed synchronism at C.

The energy relations for this process may be derived from expressions (1) and (2) in which is substituted the new synchronous speed Ω/Z. Also

$$\omega_2 = \Omega/Z \text{ and } \omega_1 = \Omega$$

Substituting in (1) and (2) there results

$$\text{rotor mechanical output} = \frac{K\,I}{2\,g}\left(\frac{\Omega^2}{Z^2} - \Omega^2\right)$$

$$= -\frac{K\,I}{2\,g}\,\Omega^2\left(\frac{Z^2-1}{Z^2}\right) \qquad (5)$$

$$\text{rotor electrical input} = \frac{K\,I}{g}\frac{\Omega}{Z}\left(\frac{\Omega}{Z} - \Omega\right)$$

$$= -\frac{K\,I}{g}\,\Omega^2\left(\frac{Z-1}{Z^2}\right) \qquad (6)$$

The negative signs show that the machine is now a generator with mechanical input, derived from the change in kinetic energy and electric output from the rotor to the stator.

If the rotor electrical output $\dfrac{K\,I}{g}\,\Omega^2\,\dfrac{Z-1}{Z^2}$ be divided by the high-speed kinetic energy from expression (3) there will result an expression showing the portion of the high-speed kinetic energy which is returned to the stator by regenerative braking. This expression is

$$\frac{\text{energy returned}}{\text{high-speed kinetic energy}} = 2\left(\frac{Z-1}{Z^2}\right) \qquad (7)$$

It is now possible to make up a table showing what becomes of the kinetic energy of the rotor and load when a shift is made to low speed and when after low-speed synchronism is reached mechanical brakes are applied. The unit of energy is the kinetic energy at high-speed synchronism.

TABLE I

Z (speed ratio)	2	3	4	6
Original kinetic energy	1	1	1	1
Portion returned to stator from (7)	0.5	0.44	0.37	0.28
Portion lost in mechanical brake	0.25	0.11	0.06	0.03
Portion lost in rotor winding	0.25	0.45	0.57	0.69
Rotor loss per cycle	1.25	1.45	1.57	1.69

The last line shows the units of energy going into rotor loss for one complete cycle consisting of starting on high speed, changing to low speed and applying a brake. If the mechanical brakes be applied and the winding disconnected before low-speed synchronism is reached, they will absorb a disproportionate amount of energy and the portions returned to the stator and lost in the rotor will be reduced.

Stator Losses

So far, emphasis has been laid upon rotor loss and little has been said concerning stator losses. The reason for this is that with a high-resistance rotor most of the power loss is in the rotor. Once the rotor loss is known

for inertia loads the stator loss is not difficult to determine since

$$\frac{\text{Stator loss}}{\text{Rotor loss}} = \frac{\text{stator resistance}}{\text{rotor resistance}}$$

where the rotor resistance is the value after being transformed to the stator. The above expression shows the advantage to the stator of the high-resistance rotor in the matter of stator loss on inertia load.

Quite obviously, then, the rotor and associated parts should have the smallest moment of inertia possible consistent with good design. Welded steel spiders which, in one case, weigh 43 lb. apiece displaced cast iron spiders which weighed 89 lb. apiece.

The problem of dissipating the heat evolved in the motor is accentuated by the fact that the ventilation is materially cut down owing to the accelerating and retarding features of the service which keep the average speed of the motor at less than one-half of the high speed. The areas of all air passages through the machine should be four or five times greater than for standard motors. This has been made possible to large extent by using arc welded steel instead of cast iron for frames. The stator is provided with ventilating fins welded in place which are in the path of the air issuing from the motor. See Fig. 1.

Noise Elimination

Noise elimination is of paramount importance in elevator motors. The magnetic hum so characteristic of ordinary induction motors becomes an insidious nuisance in a location where people must live with it. Hotels, apartments, offices and hospitals demand noiseless operation. The predominant cause of noise in induction motors is the existence of harmonics of both flux and current. The interaction of these currents and fields sets up periodic forces which in turn move the rods and teeth enough to produce noise. Pitch or coil span is known to have a vital connection with the production of harmonics and since the 5th and 7th tend to have the greatest magnitudes it is well to keep them as low as possible. This can be done by making the pitch or span equal to approximately 5/6 of a pole pitch. The number of slots per phase per pole is closely connected with the production of harmonics. Here again Fourier's analysis shows considerable improvement in this regard of a motor having two slots per phase per pole over one having a single slot per phase per pole. For this reason one should set two slots per phase per pole as the absolute minimum if one is to have a quiet motor.

Rotor Skew

An interesting problem arose in connection with the skewing of the rotor rods. It is common practise among all manufacturers to skew rotors. This has two effects which it is desired to utilize. The first and most important is that with a properly skewed rotor there are no positions of the rotor where it tends to remain locked in position due to the variation in magnetic reluctance of the air-gap as the rotor is turned. This effect, sometimes known as "cogging" produces pulsations in torque if allowed to become of too great magnitude by improper amount of skew. A second effect desired from rotor skew is to reduce noise resulting from the pulsating torque. Then a third effect forced itself into the problem of design.

The effect of skewing the rotor rods is the same as that due to the distribution of a phase group in the stator over a plurality of slots, except here the distribution is *continuous* instead of discontinuous as in the stator.

In the case of skewed rotor rods it will be seen that each elementary length of rotor rod has an infinitesimal voltage generated in it which is out of phase with that generated in the next adjoining element. The voltage generated in the rod is the integrated voltage of these elementary lengths. Vectorially we have the elementary voltages forming the arc of a circle and the sum is the chord. Hence, the voltage actually generated in a rotor rod is less than would be generated if the rod were without skew.

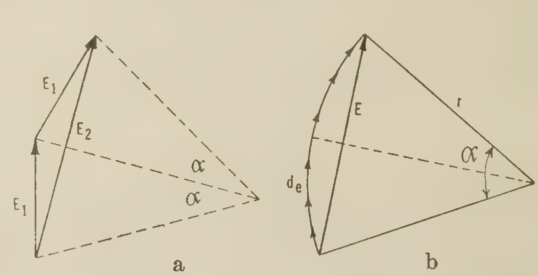

Fig. 3—Voltages in Stator and Skewed Rotor

a. Stator voltages, showing effect of distributing the winding in two slots per phase per pole. E_1 = voltage in ½ of 1 phase. E_2 = phase voltage. This effect is similar to the effect got in the squirrel-cage rotor by skewing the rotor bars.

b. Rotor voltages. With a skewed rotor bar the elemental lengths of the bars have infinitesimal voltages generated in them which are *out of phase* just the same as the voltages induced in adjacent slots of the stator are out of phase. The elemental vector voltages plotted end-on-end lie along the arc of a circle. The sum is the chord.

$$\text{"Skew factor"} = \frac{E}{\int_{\alpha=0}^{\alpha=\alpha} d\,e} = \frac{2\ r\ \text{Sin}\dfrac{\alpha}{2}}{r\,\alpha} = \frac{2\ \text{Sin}\dfrac{\alpha}{2}}{\alpha}$$

The ratio $\dfrac{\text{actual voltage generated per rod}}{\text{voltage for unskewed rod}}$ might be called "skew factor."

It will be obvious that this ratio is independent of the slip and the result is that the

Torque with skew $= S^2 \times$ torque without skew

In Fig. 4 the skew factor S is plotted against skew in electrical degrees.

Stator Copper Balance

In the case of a two-speed motor with two separate

windings the question of the proper balance of copper section between the two windings is of utmost importance. It is obvious that the proper division of slot area between the two windings depends upon the duty cycle of the elevator and the relative service demanded from the two windings. A little calculation of the losses

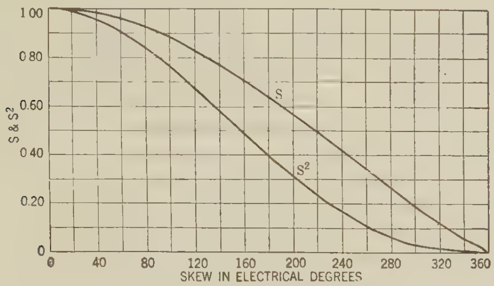

FIG. 4—SKEW FACTOR PLOTTED AGAINST SKEW

"Skew factor" $S = \dfrac{360 \text{ Sin } \dfrac{\alpha}{2}}{\pi\, \alpha}$ where α is skew in electrical degrees.

in the two windings will show that the minimum amount of heat will be evolved in the stator windings when the ratio of the copper cross-sections of the two windings is equal to the ratio of energy (not power) losses in the two windings. That is,

$$\frac{A_1}{A_2} = \frac{Q_1}{Q_2}$$

where A and Q represent the cross-sectional area of copper in the slot and the energy losses respectively and the subscripts identify the winding with which the particular quantity is associated.

TRANSFORMER EFFECTS IN TWO-SPEED STATORS

The design of the stator winding in a two-speed two-winding motor is subjected to limitations which are not present in a single winding motor because of the transformer effects between the windings.

A full account of the analysis necessary to cover the subject of elimination of harmful transformer effects is long enough to form a paper in itself so the present paper will limit itself to brief explanations of methods, followed by tabulated results which would be obtained by extensions of the methods.

ELIMINATION OF CIRCULATING CURRENTS IN THE HIGH-SPEED WINDING

We will first concern ourselves with transformer effects in the high-speed winding induced by operating the low-speed winding.

Correction by High-Speed Coil Pitch. If the speed ratio is, for instance, 2 it is evident that if the high-speed coils are wound full pitch the two conductors forming a turn will have e. m. fs. induced in them 360 deg. apart and the turn e. m. f. will be zero. We may generalize and say if the speed ratio is Z the e. m. f. per turn of the high speed will be zero if the

high-speed pitch $= \dfrac{2}{Z}, \dfrac{4}{Z}, \dfrac{6}{Z}$ etc., where Z is always taken > 1 and may be fractional or integral. The designer may, however, not wish to use the coil pitch demanded by this type of correction because it may be a pitch conducive to noise from harmonics or it may be a pitch not physically attainable with the number of slots at his disposal.

Correction in the Phase Group. In case the induced voltage per turn is not zero, the voltage per coil will be the turn voltage multiplied by the number of turns. The coils which make up a phase group are equally distributed over 60 electrical deg. in an ordinary three-phase winding. When the low speed is operating this 60 deg. is changed to $60 \times Z$ deg. This condition can be very simply shown by vectors in Figs. 5 and 6.

Group voltages on the high speed will be zero for

3 phase (60 deg. distribution) when $Z = 6$, 12 or any multiple of 6

3 phase (120 deg. distribution) when $Z = 3$, 6 or any multiple of 3

2 phase when $Z = 2$, 4 or any multiple of 2

Correction by Group Connections. In those cases where neither the turn voltage nor the group voltage can be made zero, care is necessary in connecting the groups in series-parallel connections because circulating currents may be set up. These may be eliminated by making total voltage of the groups in a series leg equal to zero or by making all series legs which are paralleled have the same transformer voltage in magnitude and phase. Figure 7 shows the arrangement of group voltages of the high speed winding when the high speed is operating. The groups of one phase are numbered 1, 2, 3, 4 etc. consecutively around the stator. The

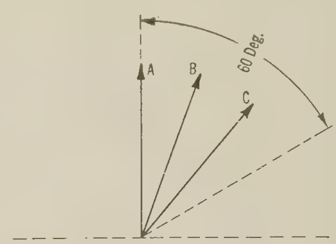

FIG. 5—VOLTAGES INDUCED IN HIGH-SPEED WINDING WHEN HIGH-SPEED WINDING IS OPERATING

In a three-phase high-speed winding the voltages A, B, C generated in the various slots of a phase group are spread over 60 electrical degrees *only* when the high speed is in operation. When the low speed is operating these vector voltages are spread over $60 \times Z$ deg.

spacing between adjacent vectors is 180 deg. If the low speed is now allowed to operate the spacing between adjacent vectors becomes 180 deg. $\times Z$. Fig. 8 shows the condition when $Z = 4$. Among the various orders of connecting the groups of a phase in series the adjacent and the alternate connections are most common. In the adjacent connection, adjacent poles are connected

in series. In the alternate connection, alternate poles are connected in series.

Table II shows the number of poles of the high speed winding which must be in series in each leg to produce zero transformer voltage when the low speed is operating Fig. 9 shows the condition illustrated above when the alternate connection is tried when $Z = 4$. Table II predicts circulating currents and we see from the figure that they will exist.

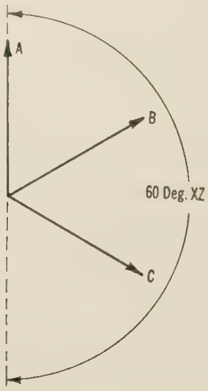

FIG. 6—VOLTAGES INDUCED IN HIGH-SPEED WINDING WHEN LOW-SPEED WINDING IS OPERATING

The vector voltages generated in a high-speed group are spread over $60 \times Z$ electrical degrees when the low speed is operating. The transformer voltage in a high-speed group is then $A + B + C$. In case 60 deg. $\times Z$ is a multiple of 360 deg., $A + B + C = O$.

TABLE II

Z	Adjacent connection	Alternate connection	
2, 4, 6, etc........	2	Impossible	Number of poles in series must be a multiple of number shown to eliminate transformer voltages in series leg of parallel connection.
3/2, 5/2, 7/2 etc..	4	2	
4/3, 8/3, 10/3 etc.	6	3	
5/3, 7/3, 11/3 etc.	3	3	
5/4, 7/4, 9/4 etc..	8	4	
6/5, 8/5, 12/5 etc.	10	5	
7/5, 9/5, 11/5 etc.	5	5	

It will be noted that the foregoing tabulation does not contain any speed ratios where Z is an odd number. The reason for this is that if the speed ratios is an odd number, it is impossible to connect the series circuits so that the voltage in a series leg is zero. See Fig. 10. This does mean, however, that there is a transformer voltage generated in each phase which voltage appears at the terminals of the machine. This fact may have a vital bearing on the type of control used with the motor.

ELIMINATION OF CIRCULATING CURRENTS IN LOW-SPEED WINDING

A little thought will show that it is impossible to annul the transformer voltage in the low-speed winding by the first two devices used in the high-speed winding, that is, by choosing a particular coil pitch or by having the voltages in a group add to zero. The only recourse in eliminating trouble in the low-speed winding is to make sure that circulating currents cannot occur in any parallels by so connecting the proper poles in series that the transformer voltage of a series leg is made zero just as was done in the high-speed winding. The following table will show the proper number of poles to be connected in series to obtain zero leg voltage for the various speed ratios and the two commonest types of connection, that is, adjacent poles in series and alternate poles in series.

FIG. 7

FIG. 8

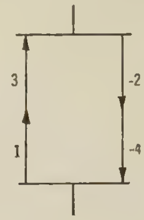

FIG. 9

FIG. 10

FIG. 7—GROUP VOLTAGES IN HIGH-SPEED WINDING WHEN HIGH-SPEED WINDING IS OPERATING

These are the four group voltage in one-phase of a four-pole stator. The distance between successive voltages is 180 electrical degrees.

FIG. 8—GROUP VOLTAGES IN HIGH-SPEED WINDING WHEN LOW-SPEED WINDING IS OPERATING

When the high-speed winding of Fig. 10 is subjected to the low-speed field of 16 poles the successive polar voltages are 4×180 deg. apart because 4 is the speed ratio

FIG. 9—LOCAL CIRCULATING CURRENTS SET UP IN HIGH-SPEED WINDING WITH SERIES-PARALLEL CONNECTION

These currents are induced by transformer effects from the low-speed winding

FIG. 10—TRANSFORMER VOLTAGES SET UP IN HIGH-SPEED WINDING WHEN THE SPEED RATIO IS AN ODD INTEGER

No circulating currents can occur but induced transformer voltages do appear at the terminals of the high-speed winding

TABLE III

Z	Adjacent connection	Alternate connection	
2...............	4	2	Number of poles in series must be a multiple of number shown to eliminate transformer voltages in series leg of parallel connection.
3...............	3	3	
3/2.............	6	3	
4, 4/3..........	8	4	
5, 5/3..........	5	5	
5/2, 5/4........	10	5	
6, 6/5..........	12	6	
7, 7/3, 7/5......	7	7	
7/2, 7/4, 7/6.....	14	7	

At the October meeting of the Administrative Board of American Engineering Council it was decided to oppose H. R. 7344 which is a bill authorizing the President of the United States to detail engineers of the Bureau of Public Roads of the Department of Agriculture to assist the governments of the Latin-American republics in matters of highway. The reason for this opposition is that the bill disguises the appropriation of Federal funds for the benefit of foreign countries and permits a double payment of salaries to certain Federal employees.

Abridgment of

The Transmission of High-Frequency Currents for Communication Over Existing Power Networks

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and

R. C. CURTIS[1]
Non-member

Synopsis.—The use of high-voltage power lines for carrier-current communication presents a number of difficulties not met in the use of simple communication circuits. This paper tells how these difficulties may be overcome without resorting to complicated transmitting and receiving equipment. The advantages of employing tuned choke coils are described. These chokes are used to isolate the communication channel from the remainder of the power system which gives in effect a simple communication circuit between communicating points.

* * * * *

HIGH-voltage power lines are constructed with such strength that they are in general superior to any communication circuit except underground cable. Experience has demonstrated that power lines withstand storms, sleet, and floods long after all other circuits are carried away. In view of the vital necessity of communication to a power company, it is but natural that the power line should be used as a communication circuit because of its mechanical superiority. Except for short distances, it also offers an economic superiority.

The method of utilizing a power line as a telephone circuit is to superimpose high-frequency currents on the power conductors. These currents are transmitted over the line as ordinary alternating currents. They are produced and received by equipment similar to the usual space radio apparatus.

In considering the power line as a communication circuit it is immediately apparent that such a circuit differs from the usual telephone line. The principal difference is that the line is operated at high voltage. This gives rise to more or less noise due to spitting insulators and similar effects. In addition the line is not a simple circuit connecting the transmitter and receiver. In practise a power line is usually part of an extensive high-voltage network with loops, taps, and spurs. Such a network is not a constant and stable system from a communication point of view because of more or less continuous changes due to switching. In general, every time a switch is opened or closed in any part of the system, it makes a change in the communication circuit.

These factors are now generally recognized although at the time this type of communication was first undertaken, the importance of some of them was not fully appreciated. In some cases it was found that the natural changes in line characteristics due to switching were so great that a satisfactory communication circuit could not be obtained.

Efforts have been made to solve this problem by modifying the communication apparatus. Modifications tending to reduce the number of frequencies per channel and the introduction of special systems of modulation have greatly increased the amount and complexity of the equipment.

By its very nature power line communication equipment should be kept just as simple and reliable as possible. Instead of complicating the equipment it is proposed to correct the trouble at its source by stabilizing the power line. The method is to insert high-frequency resistances into the power line at such points as are necessary to block off detrimental circuits and provide a clear circuit for the channel desired.

Apparatus for this purpose has been developed which has proved simple and effective. This apparatus consists of an inductance coil very similar to those ordinarily used for lightning arrester work together with the necessary tuning equipment. These tuned circuits do not absorb energy at the power frequencies nor in any way disturb the power system.

In order to appreciate the problem presented by a power network some of the properties of transmission lines at high frequencies may be noted.

A line of great length does not act like a large capacity or a large inductance but rather as a pure resistance of approximately 800 to 850 ohms for the average power line construction. The impedance of a short line open at the end varies over a wide range.

A representative type of construction is shown in Fig. 1 with the high-frequency currents superimposed between conductors "1" and "3." The attenuation ratio, that is the ratio of the current or voltage received at the distant end to that impressed at the sending end for the type of construction assumed, is shown in Fig. 2. It is interesting to note that the losses in a simple circuit are not serious. For example, the current delivered by a line 100 mi. long is 40 per cent of that transmitted. A 200-mi. line delivers 16 per cent and a 300-mi. line about 6 per cent of the transmitted current.

In Fig. 3 is shown a type of power system in which the branch lines are all of considerable length. The impedance of such branch lines when long is approxi-

1. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

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mately the characteristic impedance. Suppose it is desired to provide a communication channel between *A* and *F*, it is seen by inspection that 50 per cent of the current fed into the system at *A* is transmitted towards *B*. The part transmitted in the opposite direction is lost since it contributes nothing to the desired channel *A-F*.

When a wave reaches a junction of two long lines a

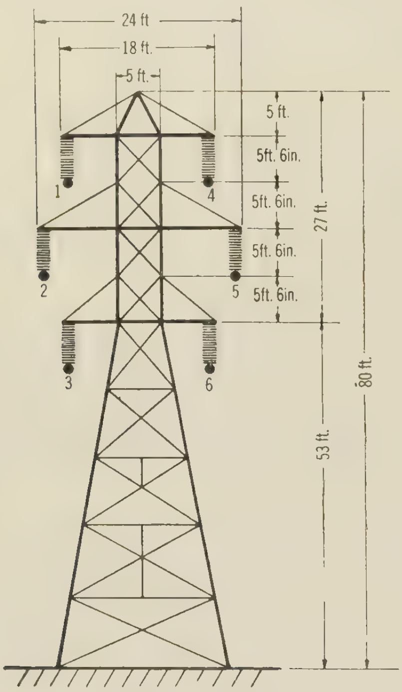

Fig. 1—Typical Line Construction

division of current takes place such that ⅓ of the original current is reflected towards the sending end while ⅔ is transmitted down each branch line, the total being ⅓ greater than the original.

The net effect of the subdivision of current at the

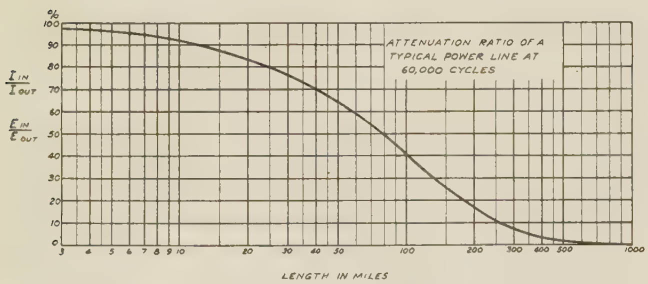

Fig. 2—Attenuation Ratio of a Typical Power Line at 60,000 Cycles

junction points is to reduce the current at *F* to 2/27 of its initial value. This is equal to the attenuation of slightly less than 300 mi. of simple circuit as seen from Fig. 2. In addition there is the loss due to the normal attenuation in the line.

Consider the case shown in Fig. 4 of a long line with a 4-mi. spur line connected on at *B*. The impedance of the 4-mi. spur line at frequencies commonly used is shown in Fig. 5. The reactance curve is seen to be a typical tangent curve except for the higher values. The reactance curve reaches a maximum and then passes through zero instead of following the tangent curve to infinity.

The impedance presented by a 4-mi. spur varies

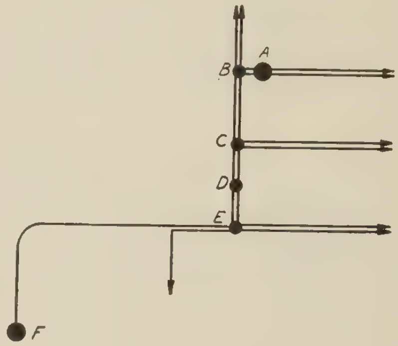

Fig. 3—Power System with Branch Lines

over a wide range. The impedance at 46.5 kilocycles is 26,000 ohms and at 58.1 kilocycles 29.3 ohms. The impedance then rises again to a maximum of 21,200 ohms at 69.7 kilocycles. The interval between the points of maximum and minimum impedance as given by equation (**19**) is

$$\frac{V}{4\,l} = \frac{186{,}000}{4 \times 4} = 11{,}600 \text{ cycles}$$

It should also be noted that the impedance between 52.5 kilocycles and 63.7 kilocycles is less than the characteristic impedance of the line and will in this band of frequencies absorb considerable energy in addition to the loss in the main line due to reflections.

The impedance of the spur line at 58.1 kilocycles is so low that less than 4.5 per cent of the current arriving at *B* is transmitted down the line towards the receiving apparatus at *C*. The effect of such a spur line is equivalent to the loss incurred in a line of over 300 mi. in length. It should be noted that at certain frequencies the effect of a single short spur line is greater than that due to the many subdivisions shown in Fig. 3.

At other frequencies the impedance of the spur line

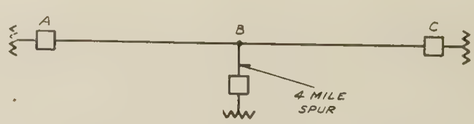

Fig. 4—Power System with a Spur Line

is very high and at these points has little or no effect on the transmission of energy from *A* to *C*. The frequencies at which these points of maximum and minimum transmission occur are a function of the length of the spur line. If a number of such spur lines of varying length is connected to the main line it may be impossible

to find a single frequency that will be satisfactory for communication.

A set of resonant line chokes may be installed in the spur line at the point where it connects to the main line. The minimum effective impedance of the spur line can thus be raised and the diversion of energy reduced to any desired amount.

Another condition often encountered is that of two or more parallel paths of slightly different lengths. At certain frequencies the current arriving by one path is exactly out of phase with the current arriving by the other. If the paths are of nearly equal length the amplitudes of the arriving currents will be very nearly equal. The two will then combine in such a way as nearly to cancel each other, leaving only a very small resultant to act on the receiver.

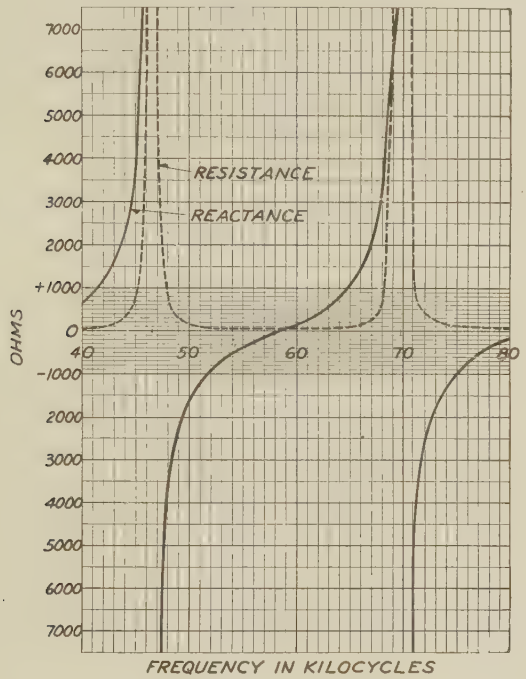

Fig. 5—Resistance and Reactance of a Four-Mile Spur Line

This condition may be corrected by inserting a set of resonant line chokes in one of the lines to prevent the flow of current by that path. Sometimes this procedure is objectionable because either of the lines may be opened during the normal operation of the system.

By inserting reactances at one or more points along the line the phase of the currents arriving at the receiving end can be shifted so that the resultant acting on the receiver is an appreciable portion of that delivered to the receiving end of the line. The construction of these phase shifting reactors is similar to the resonant line chokes. The tuning of the circuit is such as to present a reactance of the required value. In this way use is made of both the available paths. The opening or failure of one of the lines does not materially affect the communication channel.

In Fig. 6 is shown another condition met in practise in which F is energized either by way of C and D or by E. The loop is not maintained closed in normal operation of the power system. The communication channel is from A to F.

If the loop is opened at C, D, or E the effect is that of two spur lines connected across the communication channel. If the loop is opened at B or F the effect is that of one spur line. It is necessary to provide for communication over either circuit so that high impedance line chokes cannot be used at B and F to isolate one circuit.

The corrective measures in this case consist of installing at B and F in both circuits, resonant line chokes adjusted to an impedance such that a considerable amount of current can pass through the circuit to F. At the same time the impedance is high enough to prevent an excessive amount of current flowing when the circuit becomes part of a spur.

The effect of spur lines is very detrimental. The short lines cause excessive transmission loss over wide bands of frequencies and the longer lines cause distortion due to the rapid variation of impedance with frequency. All types of telephone communication utilizing high-frequency currents require the transmission of a band of frequencies rather than a single frequency. The width of the band may be reduced to some extent by employing special types of modulation. The best that can be accomplished in this direction will not reduce the width of the band below 2000 cycles. This gives only a minor improvement without providing a general solution to the problem.

The detrimental effects of spur lines may be obviated by making certain changes in the transmission system. Any desired frequency can then be used, distortion is eliminated, wide fluctuations in signal level are prevented, and complications in the transmitting and receiving apparatus are avoided.

These results can be accomplished by inserting in the power conductors, equipment which will carry the power current without loss and at the same time introduce high impedances to the communication currents.

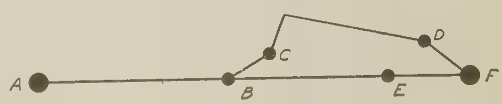

Fig. 6—Power System with Loop

The impedance of some types of transformers is quite low at high frequencies. Other types have been encountered in which the impedance varies with the instantaneous values of the power current giving the effect of modulation on the high-frequency currents. These conditions may be remedied by the use of the resonant line choke to prevent any appreciable amount of high-frequency energy being absorbed in the undesirable circuits.

Power lines are now being studied very carefully before any attempt is made to install power line telephone equipment. Actual tests have demonstrated the validity of the commonly accepted theory of lines for high frequencies. By applying accepted analytical methods, the important features of the line characteristics may be determined. If these are found to be unsatisfactory, corrective impedances are inserted at such points as will give the desired results.

Resonant Line Chokes

Physically the resonant line chokes are dividing into two classes. The single layer type is used for introducing moderate amounts of resistance into the power line and the double layer type for introducing a high resistance to isolate an undesirable circuit. The single layer resonant line choke consists of an inductance coil similar to a standard lightning arrester choke and the necessary tuning equipment. The double layer type is similar except that the number of turns on the inductance coil has been doubled by the addition of another layer of winding.

The tuning equipment diagram of connections is

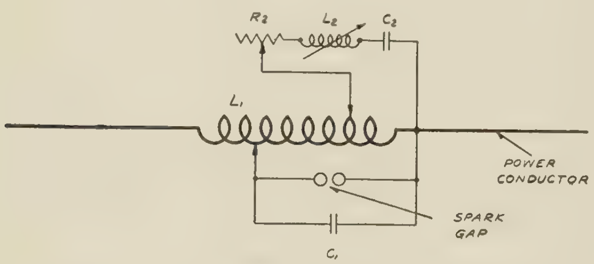

Fig. 16—Diagram of Connections for Resonant Line Chokes

given in Fig. 16. The condenser C_1 is used to tune the main inductance coil L_1 to the frequency it is desired to obstruct. An additional tuned circuit L_2, C_2 coupled to the main coil L_1. It also contains an adjustable resistance R_2. The function of the second circuit is to broaden the resonance curve so as not to injure modulation. By tightly coupling the second circuit to the first, the system is made to tune to two frequencies. In this way a single choke can be made to block two frequency bands. By varying the adjustment of this circuit the impedance presented by the choke can be changed from a high impedance over a narrow band of frequencies to a moderate impedance over a wide band of frequencies.

A typical impedance curve for the double layer type of choke is shown in Fig. 17. Chokes are placed in each of the line conductors so that the total line-to-line impedance is of the order of 12,000 ohms as compared to the line characteristic impedance of 825 ohms. It is evident that a circuit isolated by this type of choke cannot divert any appreciable amount of the communication current.

In Fig. 18, curve No. 1 shows the resistance curve of a single layer choke adjusted to give a moderately high resistance at two frequencies. By the use of this type two channels can be cleared. A resistance of approximately 400 ohms per choke is sufficient to limit the current in an undesirable circuit to a value that will not seriously affect the communication channel.

The adjustment may be changed so as to give a very flat impedance curve as shown in curve 2, Fig. 18. This is a very valuable characteristic, and is used where it

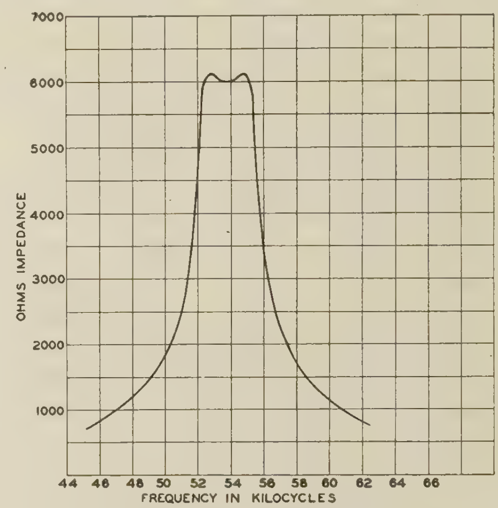

Fig. 17—Typical Impedance Curve for a Resonant Line Choke, Double Layer Type

is necessary to stabilize a power system and still transmit through the chokes as in the case shown in Fig. 6.

Conclusion

The ideal condition for a high-frequency telephone system is to have the line a simple circuit directly connecting the points between which communication is required. This ideal may be approximated as closely

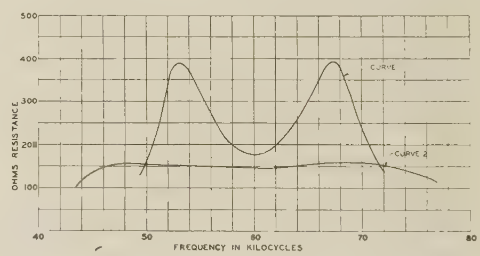

Fig. 18—Typical Resistance Curves for Resonant Line Chokes, Single Layer Type

as desired by isolating the channel from the rest of the power system. This is made possible by the installation of resonant line chokes at appropriate points.

Some of the advantages gained are:

1. Increased stability.
2. Improved quality of speech transmitted.
3. Reduction in the noise level due to the greater energy delivered to the receiver.
4. Freedom from variation in signal due to switching.

5. Simple transmitting and receiving equipment satisfactory on complex systems.

6. Increased reliability.

7. Ability to transmit through practically any type of system.

8. Ability to utilize all lines between communication points.

9. Interference with equipment on adjacent power systems can be eliminated.

10. Reduction in field work at the time of installation.

The application of the established line theory to the analysis of power lines has materially advanced the art of telephone communication over power lines. It is now possible to predict with reasonable accuracy what frequencies can be successfully transmitted over a given power network. This materially reduces the extensive field work which has often been necessary when making an installation. If the analysis shows that there are conditions which prevent the use of the desired frequency bands, corrective measures may be taken by installing resonant line chokes at suitable points. System limitations are largely overcome by this procedure and the field of application of high-frequency communication materially increased.

Abridgment of

System Stability as a Design Problem

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Synopsis.—Under modern conditions of operation the ability of the component machines of a power system to hold in step during system disturbances has become of major importance in the choice of system layout and machine design. This situation has greatly stimulated activity in the study of the problems involved. This paper reviews the general problem in the light of recent analytical and experimental studies made by the authors. The subject matter of the paper is grouped according to the following headings;

Part I reviews the factors affecting stability, including generator short-circuit ratio, voltage regulators, excitation systems, neutral impedance, governors, amortisseurs, intermediate condensers.

Part II gives methods of calculating stability, under the following heads: preliminary calculations, idealized case of two machines, general case of two machines, extension to include more than two machines, simplified method of calculating tie lines.

The appendixes include an example illustrating the method of calculation in a particular case.

* * * * *

ORIGINALLY the maximum power output of synchronous apparatus was fixed by the maximum current which the machines could supply without excessive heating, while the maximum power which could be transmitted economically over a transmission line was determined by the allowable losses in the line.

However, as progress was made in the design of electrical machinery and as the voltages at which power was transmitted were increased, it was found that the line and machine reactances must be held low enough to avoid the possibility of pull-out or instability, whether occasioned simply by excessive loads or by system disturbances.

Practically, this situation was met principally by designing generators with short-circuit ratio sufficiently high, and line reactance low enough to meet ordinary requirements. At the same time, however, the latent economic advantages in view have greatly stimulated interest in the development of means auxiliary to these, by which increases in stability of operation can be economically effected.

Further, in order to make possible the design of systems on a rational basis there has been an active demand for more accurate methods of calculating stability. The present paper gives first, a brief review of the principal factors affecting the stability of power systems; then, a summary of some of the methods of calculation which the authors have employed in the study of practical systems.

Part I

Review of Factors Affecting Stability

a. Generator Short-Circuit Ratio. In general, the maximum power that can be delivered by a synchronous generator depends upon the character of the load circuit to which the generator is connected. By way of illustration, suppose that a turbo alternator is supplying power for an induction motor load connected directly to its terminals, and suppose that as the induction motor load is gradually increased, the generator terminal voltage is maintained substantially constant by occasional manual adjustment of the generator's exciter field rheostat. Neglecting saturation, if the induction motor is of normal design, and is supplying a constant torque load, the torque at instability is found to vary in this case with generator per unit reactance, as shown by the lower curve of Fig. 3.

On the other hand, if the load torque is proportional

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to the square of the speed, *i. e.*, to $(1-s)^2$, as would occur substantially with a fan or centrifugal pump load it is impossible to find any condition under which the motor can be unstable. However, there is a maximum torque which can be carried in this case. This is shown by the upper curve of Fig. 3.

It will be seen that for constant torque load the generator synchronous reactance must not exceed approximately 1.20 for stability at full-load. In practise, the effects of saturation and of any shunt load will be to permit a higher value of machine reactance with stability.

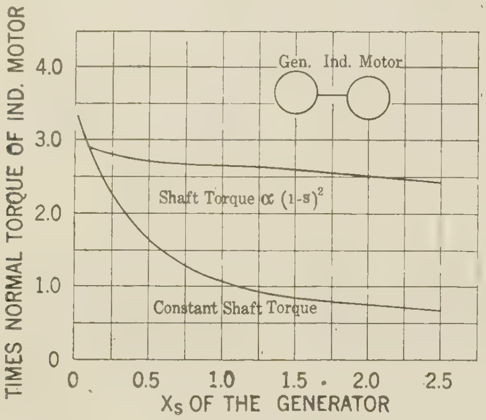

Fig. 3—Calculated Values of Maximum and Critical Torque of Induction Motor Connected to a Synchronous Generator, as a Function of Generator, Synchronous Reactance, (X_S)

Were the induction motor replaced by a synchronous motor the generator and motor per unit synchronous reactances could not exceed unity for stability at full load, while if the generator and motor are separated by a transmission line it is necessary that their reactances be less than unity for stability under the same conditions. Actually, of course, as mentioned in the previous instance, the effects of saturation and of impedance load are to reduce the requirements as to low synchronous reactance, or what is substantially the same thing, high short-circuit ratio. Nevertheless, even considering this circumstance, the fact remains that machines which are to be operated with manual control of excitation require in general a short-circuit ratio in the neighborhood of unity,[1] especially if ability to operate through severe system disturbances is desired, while if long distance transmission over high-voltage lines is involved a short-circuit ratio considerably higher than unity may be found advantageous.

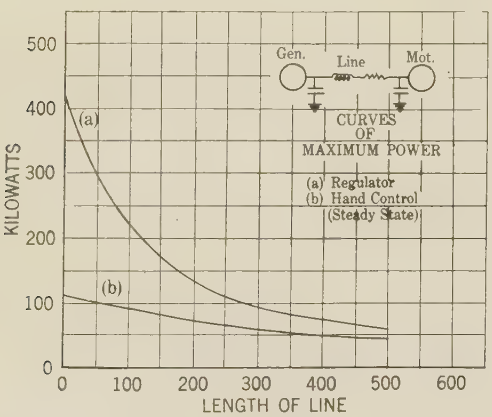

Fig. 4—Test Data

Steady load which can be carried over model line, (exciter speed less than 250 volts/sec.)

When synchronous machines were first being built this limitation was not felt, since the requirements for inherent voltage regulation necessitated construction with high short-circuit ratio. The advent of the Tirril regulator largely disposed of this necessity. This circumstance, together with the development of improved designs permitting greater current loading of the armature, has established a considerable inducement toward the use of machines of low ratio both from the standpoint of reduction in first cost and improvement in efficiency. On the other hand, power transmission developments have tended to demand a high ratio.

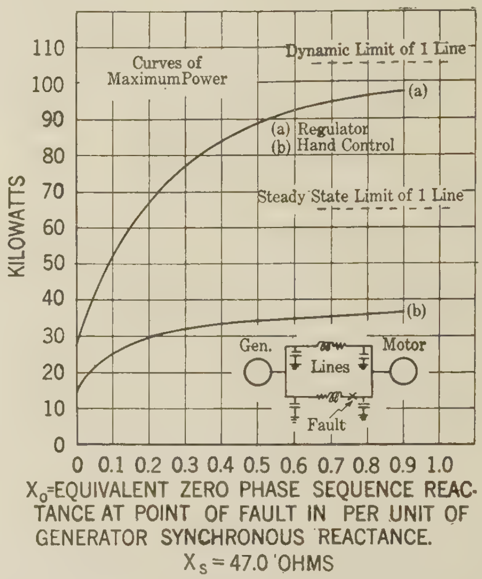

Fig. 5—Test Data

Power which can be carried through a line to ground fault on one of two parallel 250-mi. model lines. Fault cleared at both ends of line in 0.6 sec. Fault on generator bus corresponds approximately to $X_O = 0.10$; fault at other points of the line correspond to $X_O > .1$

(Exciter buildup speed of 225-250 volts per sec.; exciter ceiling 320 volts; exciter operating voltage 70 volts)

b. Voltage Regulators. If the excitation voltage can be continuously varied in proper phase relation to the machine terminal voltage it is possible to operate above the limit of stability with hand control. Recent tests have shown that when an appropriate type of regulator is employed a large gain in stability is available both under steady and transient conditions. Thus, Fig. 4 shows the gain in steady-state stability due to such a regulator as a function of the length of the transmission circuit. In the case of system disturbances the regulator has an additional function to perform; *viz.*, to effect rapidly a substantial increase in the exciter

1. Bibliography 11.

voltage, thus reducing the decrease of field flux linkages which would otherwise occur, or actually causing them to increase. In practise the gain to be anticipated in stability through faults depends both upon the regulator's ability to effect rapid increases in excitation and upon its ability to resume "balancing" after the initial phase of the disturbance is past.

The magnitude of the gain to be anticipated in practise is illustrated by Figs. 4 and 5.

Besides its effect in increasing the stability of machines of normal design, the regulator should make possible the utilization of machines of lower short-circuit ratio than would otherwise be practicable, for by its action it provides the stability that could not otherwise be obtained in machines of this type.

The regulator has a further field. It may also be applied with benefit to synchronous motors and frequency converters, especially when severe load surges are to be encountered. The gain to be anticipated should be especially great with this class of apparatus since it operates substantially from an infinite bus; *i. e.*, there is no transmission line.

c. *Excitation Systems.* The gains in stability which can be effected by a voltage regulator of a given type depend upon the rate of voltage build-up of the exciter, and upon its operating and ceiling voltages.

The available data indicate that if normal ceiling voltage is available, a moderate speed of excitation,—say 150 to 200 volts per sec.[2] for large machines—is sufficient in the usual case to prevent pulling out of step on other than the first swing of the machine rotors. In general, the gain due to a higher speed of build-up than this is small in comparison with the gain obtainable with the speed of excitation referred to, since with these higher speeds, the time available for modifying the rotor flux linkages is small (of the order of ¾ sec.). Thus, careful step-by-step calculations were made in the case of three representative systems in which water-wheel generators feed load centers over transmission lines of respectively 60, 120, and 250 mi. The results showed that the power which can be carried without pull-out on the first swing of the machine rotors, after the occurrence of a line to ground fault on the generator bus, is only from four to six per cent more with excitation sufficient to maintain constant rotor linkages[3] than can be so carried with a speed of excitation sufficient to prevent pull-out on the second swing, *i. e.*, about 150 to 200 volts per sec. This conclusion is borne out by the test data in Fig. 6 which shows the gain in transient stability as a function of exciter speed for a line to ground fault on one of two 250-mi. lines.

As these data were taken with small machines the excitation speeds shown should be multiplied by a factor less than unity in order to pro-rate them to correspondence with large machines. This factor probably ranges from 0.5 to 0.6.

On the other hand, in some cases, and especially in connection with synchronous condenser stations, it may be desirable to secure additional stabilizing action by building up the machine excitations to a very high value within a fraction of a second. To achieve this result requires a new type of exciter; one with a high ceiling voltage, and with a correspondingly high speed of build-up.

d. *Neutral Impedance.* The generally admitted circumstance that the majority of transmission line lightning flashovers establish arcs from one line to ground, and thus that this type of fault is of primary importance in determining the transient stability of transmission systems, suggests the desirability of using current limiting resistors or reactors in the high-voltage transformer neutrals, or as an equivalent grounding the neutral, and designing the transformer for high-impedance to ground current.

Obviously any means for reducing the magnitude of the system fault current is beneficial from a stability standpoint. In general, however, it is desirable that enough reactive current be permitted to flow to allow rapid selective relaying by ground current relays, and to avoid the possibility of arcing grounds. Consideration is invited to the greater use of reactors instead of the usual resistors. In principle, a reactor in the neutral is no more likely to cause excessive system voltages than a grounding transformer is, that is, precautions against excessive voltages are not necessary unless the reactor approaches the dimensions of a Petersen coil. Also even with a Petersen coil there does not appear any source of danger which cannot be overcome with relative simplicity. In most cases, however, very large gains in stability are obtainable with reactors which do not even approach to the Petersen coil value, *i. e.*, to a value such that the reactor current equals the fault charging current.

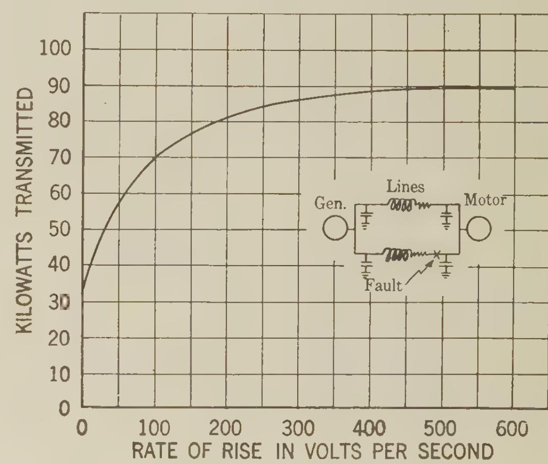

FIG. 6—TEST DATA

Showing the effect of speed of excitation on the transient stability of the model transmission system (ceiling voltage 320 volts; operating voltage 70 volts)

2. For 250-volt fields. One-half as much for 125-volt fields.

3. Equivalent to about 600 volts per sec. with a normal ceiling exciter.

The principal advantage of reactors as compared with resistors is their greater reliability, usually lower cost, and the fact that in case of line to ground fault they tend to increase the phase to ground voltage on the clear phases to a much lower extent. This last factor which is illustrated in Figs. 7 and 8 is of great importance in connection with duty on lightning arresters. In order to obtain an appreciable gain in stability the resistance must be considerably greater than the system reactance viewed from the point of fault. Referring to the figures this means that the voltages to be anticipated from a clear phase to ground are necessarily $\sqrt{2}$ or more times normal voltage.

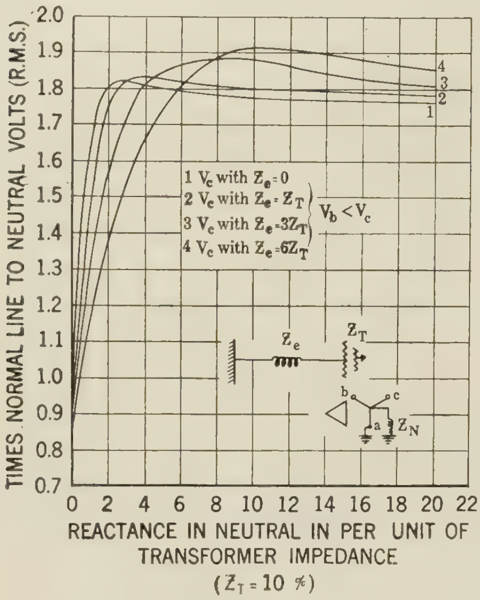

Fig. 7—Calculated Line to Ground Voltages on the Open Phases with a Line to Ground Fault, as a Function of Reactance in the Neutral

With a reactor this is not the case, and in fact a marked gain in stability can be obtained with a value of reactance such that clear phase to ground voltage is say less than 30 per cent more than normal.

Although the use of grounding reactors of high enough reactance to approach the Petersen coil value has not been recommended generally, it is felt that in a large number of cases the use of Petersen coils may nevertheless be desirable, provided that suitable precautions are taken to prevent the occurrence of excess voltages during switching.

e. Governors. In a considerable number of instances momentary system disturbances have been followed by prolonged hunting due to "pumping" of the steam turbine governors. This condition usually arises when the regulation of the governors, that is, the speed range from no-load to full load with synchronizing spring fixed, is unduly low. To avoid hunting of this character it is desirable that the regulation be four per cent or above.

f. Amortisseurs. In general any damping influences in a system tend to improve stability, and especially in connection with systems involving a number of independent machines each of which is capable of swinging more or less independently of the others. Further, when high resistance lines are involved, stable operation of laminated pole machines without damping windings may be impossible under some load conditions. A consideration of these factors suggests the general desirability of equipping water-wheel generators with low resistance amortisseur windings.

g. Intermediate Condensers. The use of synchronous condensers or of synchronous condensers in combination with shunt reactors is some times preferable to the construction of additional overhead line. In such cases, however, it is probably desirable that use be made of a balancing type of voltage regulator, as the stabilizing influence of the condenser is greatly increased in this way. Thus, shop tests on a model 500-mi. line show the following results:

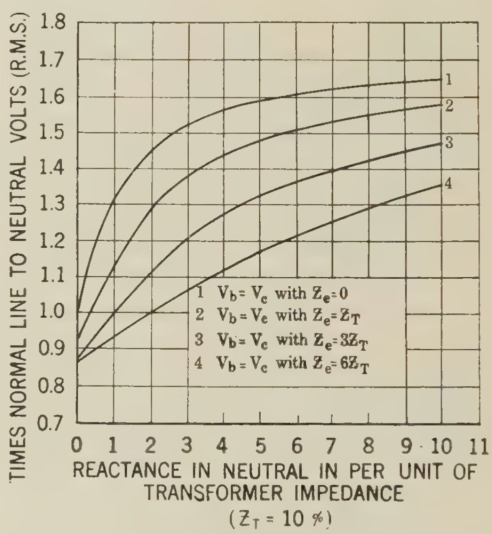

Fig. 8—Calculated Line to Ground Voltages on the Open Phases with a Line to Ground Fault, as a Function of Reactance in the Neutral

Gain in steady power limit over hand control value with no condenser,

a. With regulator on generator and motor but no condenser 21 per cent.

b. With intermediate condenser equal in size to generator and motor but hand control on all machines 25 per cent.

c. With intermediate condenser and regulator on all machines 99 per cent.

Abridgment of

High-Voltage Phenomena in Thunderstorms

BY MARCEL A. LISSMAN[1]

Associate, A. I. E. E.

Synopsis.—*Lightning phenomena are analyzed in the light of laboratory experience with high-voltage phenomena in the atmosphere. Special emphasis is placed on the effect of space charges in producing high local stresses when mobilized through channels of high conductivity caused by high temperatures. A detailed analysis is included of the steps through which air at atmospheric pressure passes when, due to applied electric stresses, its electric properties change from those of a non-conductor to those of a highly conducting body,—perhaps many times as conducting as a metallic conductor at ordinary temperature,—and then again resumes its original non-conducting properties.*

* * * * *

THE electrical quantities involved in thunderstorms are of an order of magnitude different from those encountered in ordinary engineering experience. In the laboratory, sparks 20 ft. in length have been obtained with an applied potential of 2,000,000 volts, 60 cycles. Compared with a lightning flash several miles in length these results seem puny indeed. Yet the results obtained in the laboratory enable us to analyze the phenomena occurring in nature, and thus obtain a clearer mental picture of the mechanism involved in the formation of lightning flashes.

The conductivity of the atmosphere is due to the presence of ions which, when acted upon by an electric field, give rise to a displacement current. If it were not for these charged particles, air would be a perfect insulator. Ions are always present in the atmosphere, as they are formed spontaneously due to the action of traces of radio active matter, cosmic rays, etc. However, the conductivity which these sources of ions lend to the atmosphere is so small that it has no engineering significance. When the saturation current is not reached, that is, when the ions are not removed by the field as fast as they are formed, then the current through the air is proportional to the voltage gradient and to the cross-section of the path. In symbols, the relation is

$$I \, \alpha \, G \, . \, A \qquad (1)$$

where I is the current, G the voltage gradient, and A the cross-section of the path considered.

Relation (**1**) represents the behavior of air under low voltage stresses.

When the voltage is gradually raised, the saturation current is soon reached. The voltage can then be raised considerably without change of current. However, as soon as the voltage gradient at some point in the field reaches 76 kv. per inch, the current suddenly increases. Thus is due to the cumulative effect of collision ionization. Ions present in the field are then so accelerated between collisions as to possess sufficient kinetic energy to produce new ions when they collide with neutral atoms. The rate of formation of ions is thus enormously accelerated. The clouds of ions thus formed are referred to as space charges and greatly disturb the original electric field. The action of space charges upon the electric field is always such that it prevents the gradient from rising above the critical value of 76 kv. per inch where the stress is most intense. Outside the region of breakdown the gradient is increased above the value it would have for the same applied voltage if the space charge were not present. This is illustrated in Fig. 1, *a* and *b*. The body A is at a positive potential and B at a negative potential, the configuration being such that the electric field diverges from A. If the potential between A and B is raised, the gradient in the neighborhood of A soon reaches the critical value for air.

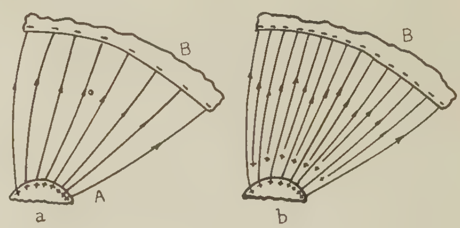

FIG. 1

Collision ionization then enormously increases the supply of ions in that region. The negative ions travel towards A and become discharged. The positive ions travel toward B and form a space charge. At 1*b* the applied potential is much greater than at 1*a*, yet the gradient in the neighborhood of A has not been increased. However, the gradient between the space charge and B is greatly increased, as shown by the additional lines of force originating on the space charge and terminating on negative charges at B.

When collision ionization takes place in a restricted region of a divergent field, the resulting phenomena are referred to as corona. Even though the initial electric field might have been symmetrical, the appearance of corona shows a strong tendency of the corona current toward concentration into preferred paths of restricted cross-section compared to the cross-section which seems available from mathematical considerations. This

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tendency results in the formation of corona streamers. It may be represented in symbols by the relation

$$g \,\alpha\, A \,.\, F\,(i) \qquad \textbf{(2)}$$

or the conductance, g, varies as the cross-section of the path and some function of the current density, i. The function $F\,(i)$ is such that the increase in conductance resulting from an increase in current density more than offsets the decrease due to the reduction in cross-section.

The formation of corona streamers is the first stage in the building up of preferred discharge paths of restricted cross-section. The various manifestations of corona, such as light, sound, and chemical changes, show that considerable ionic activity is present in corona streamers. Physicists give us plausible reasons why such intense ionic activity in corona streamers should have a tendency to lower the critical gradient of cumulative collision ionization. Some results obtained by them with the discharge tube suggested that the bluish light observed was not due directly to the recombination of ions. At the low pressures used, the velocity of the ions due to the electric field would be such that the Doppler effect should be observed. As this is not the case it has been concluded that the sources of light were neutral atoms not affected by the electric field, and consequently at rest. An explanation which has been proposed is that when ions of opposite sign recombine to form neutral atoms, *i. e.*, when a positive nucleus recaptures a lost electron, the quantum of energy radiated is in the form of very short wavelengths ouside the visible spectrum. These rays are supposed to have a very limited range. They have the power to excite neutral atoms; that is, they furnish sufficient energy to a neutral atom to lift one of its electrons from an inner stable orbit to a less stable outer orbit, where the electron possesses potential energy with respect to the nucleus. The electron upon falling back to a more stable orbit radiates this energy at a longer wave length which falls in the visible spectrum. It is this light emanating from neutral atoms which is observed.

With the above in mind, we must consider that the intense ionic activity in a corona streamer is due to the active recombination of ions constantly taking place. Due to such active recombination a considerable number of neutral atoms in the streamer are excited, that is, the electron has already been furnished part of the work required for complete ionization. For these excited atoms a collision of lesser magnitude, corresponding to a lower voltage gradient, will suffice to complete the work of ionization.

As the current density in a streamer further increases, temperature begins to play a more important part. In the final stage, a high degree of conductivity, perhaps greater than that of metallic conductors of the same cross-section, is imparted to the filamentary channels due to the very high temperature attained as the result of the large amount of energy released per unit volume in the conducting path. It is probable that when the temperature in the filament is sufficiently high, the violent thermal agitation of the gas suffices to keep up a supply of ions great enough to account for the high conductivity attained. This final stage in the condensation of the discharge into narrow filamentary channels lends itself particularly well to analysis and will be discussed here, but it must be remembered that the change from the initial corona streamer is gradual and not in distinct steps.

Let us assume that a discharge is being transmitted from a to b, Fig. 2, along a cylindrical path. Some heat will be generated by the passage of the discharge. At low temperatures the heat will be dissipated mostly by conduction or convection across the cylindrical boundary surface. We can reasonably assume that the conductance of the path varies in some manner with the temperature, T. This will be the case when the thermal agitation of the gas becomes so high that a certain proportion of the collisions will result in ionization. Theoretically, for any temperature above absolute zero, some velocities will be sufficiently high to cause ionization, but the probability of such velocities at low temperatures is vanishingly small. However, this probability

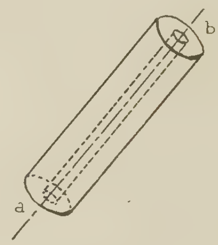


FIG. 2

increases rapidly with the temperature. The ions when free are acted upon by the electric field and subjected to a drift which is superimposed upon the random thermal agitation and is equivalent to a current. Thus the path has some of the properties of metallic conduction. The current will depend upon the proportion of free ions, and this in turn will depend upon the temperature. We can therefore write

$$g \,\alpha\, A \,.\, F\,(i, T) \qquad \textbf{(2a)}$$

or the conductance varies as the cross-section of the path and some function of the current density and temperature.

This relation is essentially unstable, because the temperature reached is caused by the energy loss per unit volume, and therefore depends on the current density, and the current density for a given voltage gradient depends on the conductivity which increases in some fashion with the temperature.

Coming back to the cylindrical path a–b, Fig. 2, the heat generated by the passage of the discharge must at first be dissipated mainly by conduction or convection through the cylindrical boundary. Therefore, the

temperature reached in the interior will be higher than the average, so that the degree of ionization will also be higher. As the conductivity increases with the ionization, the current density will not remain uniform but will be higher where the temperature is higher. This means that in a restricted region of the path along its axis the rate of dissipation of energy will be increased, causing a further increase of temperature. This process continues until some limiting action takes place, so that finally the discharge will be concentrated in a narrow thread-like filament and will require a smaller voltage gradient than initially.

The limiting action referred to is not far to seek.

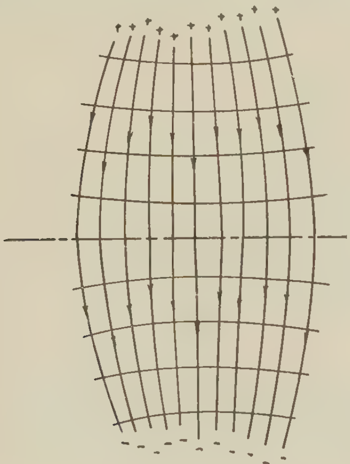


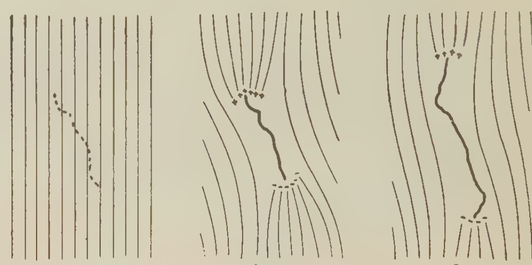
Fig. 3

When the temperature is very high, radiation has a greater influence upon cooling the filament than conduction. The radiation of a black body varies as the fourth power of the absolute temperature, and such a relation is more than ample to limit the path to a finite cross-section by limiting the temperature which the filament might attain.

In a thundercloud, positive and negative charges are distributed throughout great volumes of cloud in the form of large ions having low mobilities. It is convenient to represent the stress to which the intervening air is subjected by drawing lines from any suitable unit of positive charge to a similar unit of negative charge, as shown in Fig. 3. In Fig. 3 the lines are drawn from a positively charged portion of cloud to a negatively charged portion,—or the neutral plane might be considered to represent the ground surface, in which case the negative charge is an electrical image of the positive charge—a great help in computing the field between a charged body and the ground.

If in Fig. 3 we consider the neutral plane to be the ground surface, it is seen that the stress is smallest at the ground because the lines of force are farthest apart there. This will always be the case, as the lines of force must either originate or end on the charges in the cloud depending upon the polarity—a pure convention—but will then spread apart in such a manner that the permittance of the path between cloud and earth is maximum. Due to irregularities at the ground surface there will no doubt be high local stresses, but even if breakdown takes place, this as a rule will result only in the formation of a local space charge which will be sufficient to relieve the stress, because the volume of overstressed air is small. Breakdown will generally take place in the cloud due to the wind shifting the charges in such a manner that a large volume of air becomes overstressed. This is necessary in order that sufficient energy be available for the formation of filaments of high conductivity. These conducting paths then transmit the high stresses to their end points and lengthen by successive breakdown of the air.

The manner in which a filament of high conductivity transmits the stress to its end points will now be illustrated. Fig. 4A shows the lines of force in a parallel field, the voltage gradient being considerably below the critical value for air. Let the dotted line represent a channel of high conductivity caused by thermal dissociation. This channel contains both positive and negative ions in equal numbers so that their total effect upon the external field is zero. The ions continually form and recombine, the percentage of atoms ionized at a given temperature of the channel remaining constant. While the ions are free they are acted upon by the electric field, so that a small unidirectional shift is superposed upon their random thermal agitation, the positive ions shifting towards one end of the filament and the negative ions shifting towards the other end.



a b c

Fig. 4

This takes place along the whole length of the channel, and although each ion may shift only slightly, if their number is large the total effect might represent a very large current. Due to this shifting caused by the electric field, ions of one sign will accumulate at one end of the filament and ions of the opposite sign at the other end. Such an excess of ions of one sign at the ends of the filament alters the original field in a manner shown at 4B. It is seen that the gradient at each end of the filament has been considerably increased, while the gradient along the filament, which causes the shifting action, has been decreased.

If the energy initially stored in the dielectric is too small, the shifting action in the filament will cease as soon as the voltage gradient along the filament falls to a sufficiently low value. This will happen before the

critical gradient for air has been reached at the end points. The conductivity of the filament is due to the high temperature caused by the passage of the current in a very restricted channel, and as soon as the current decreases the filament will cool and its resistance will increase. This will decrease the current still further, resulting in additional cooling and increase in resistance. This action will continue at an accelerated rate until all traces of the path have disappeared, just as if a switch had suddenly been opened.

On the other hand, if the energy stored in the dielectric is sufficiently high, then the critical gradient for air will be reached at the end points before the gradient along the channel has fallen to the point where the resulting current fails to maintain thermal dissociation in the channel. As soon as the critical gradient is reached at the end points, collision ionization takes place and corona streamers form radiating outward from the point. As a rule, thermal dissociation will first become effective in one of these streamers. When this takes place large currents will flow along this streamer in the manner outlined above, resulting in a considerable reduction in the voltage gradient. The high gradient required to maintain the action along the other corona streamers having collapsed, the activity in them will stop. Fig. 4c illustrates the lengthened channel, showing already an accumulation of charges and in-

Fig. 5

creased gradients at the end points. The channel continues to grow in this manner as long as the gradients at its end points reach sufficiently high values to cause local breakdown of the air.

The conductivity reached in a channel where thermal dissociation takes place depends solely on the current density and resulting temperature, so that the gradient along the channel may fall to a value as low as a few hundred volts per foot, while the original gradient may be as high as 100,000 volts per foot. Thus, as soon as the conducting channel reaches a length of several hundred feet, the energy available to cause breakdown at its end points becomes very large. The voltage gradient accumulating at the end points is limited by the breakdown strength of air which results in lengthening the channel. The voltage used up in this manner might reach five million volts. For a strong initial field, the rate of breakdown and lengthening of the filament increases.

The channel will continue to increase in length, branching out in the clouds wherever the necessary gradient is available, until the potential of the cloud has been so reduced that the current density in the channel can no longer be maintained, when the action stops in the manner outlined above. Fig. 5 illustrates a cloud discharged in this manner. The dotted lines show where the conducting filaments were located. It will be seen that the initial charges are still located in the cloud. Wherever the gradient was sufficiently high, ionization channels formed which planted space charges of opposite

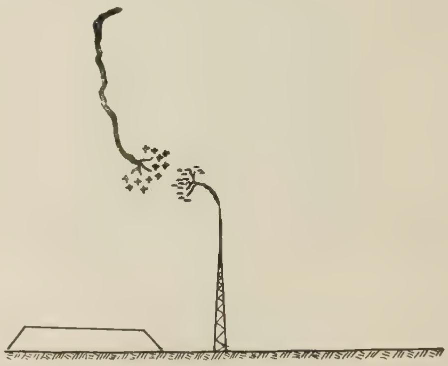


Fig. 6

sign throughout the body of the cloud. The potential of the cloud has thus been considerably reduced. The gradient between opposite charges in the cloud is still quite high, and the charges gradually neutralize each other due to convection. However, the resultant gradient between cloud and earth has fallen to such a low value that it cannot permit the growth, or even maintain, conducting channels.

It remains to indicate what bearing the above analysis may have on the possible application of a scale factor to laboratory experiments in lightning protection. Even the tallest lightning rods distort the general field of a thundercloud to such a slight extent, that they scarcely can have any influence on the instigation and guidance of a lightning flash. Whenever a lightning flash originates in the clouds and grows toward a lightning rod, during the period of growth the gradient at the rod increases, at first slowly, then more rapidly as the end of the conducting channel comes closer to the rod. When it approaches within less than 100 feet from the rod, the gradient at the rod might reach a value of the order of 300,000 volts per foot. This is illustrated in Fig. 6. The voltage gradient and volume of overstressed air at the rod then becomes sufficiently great to permit the formation of a streamer of high conductivity starting out from the rod and growing in the general direction in which the field is most intense. When this occurs, the gradient between the ends of the

growing lightning flash and the streamer from the rod may reach values several times as great as the gradient in any other direction, and the two ends therefore grow towards each other until they ultimately connect. This explains why lightning hits elevated points which initially do not sufficiently distort the original field to guide the flash.

Similar considerations show why some lightning transients on transmission lines may have steep wave fronts of the order of a few microseconds. If a lightning discharge strikes very close to a transmission line, the voltage gradient at the point of nearest approach first increases slowly, reaches a maximum and then suddenly collapses in the time required for the flash to bridge the last 100 feet or so of the gap. The latter time depends upon the driving power behind the flash; that is, the energy initially stored in the electric field of the thundercloud.

The Graphic Solution of A-C. Transmission Line Problems

BY F. M. DENTON[1]

Fellow, A. I. E. E.

Foreword.—*The success of the series capacitor in increasing the load capacity, as well as improving the regulation of those a-c. transmission lines on which it has been tried,[2] promises to lead to its wide adoption. The high loading and excessive short-circuit currents entailed by the series capacitor have to be cared for by safety devices, and in order to be able to design and properly locate such devices, it becomes essential to predetermine the values of current and voltage at every point along the line.*

Synopsis.—*A step-by-step method is described for drawing the complete polar vector diagrams of current and voltage in an a-c. transmission line supplying a given load. Its chief novelty consists in the use of celophane tissue instead of ordinary drawing paper. Such tissue is easily obtained commercially, as it is used chiefly for wrapping candy boxes. It is transparent, thin and flexible and takes ink well.*

The usual implements, such as scales, protractors, triangles and compasses, are unnecessary. The required vector scales, impedance triangles, and multiplying triangles are laid out in ink upon a sheet of squared paper mounted on a drawing board, and the vector diagram is produced on the superimposed celophane by tracing, the celophane sheet being shifted as required in determining successive points on the vector diagram.

It is true that no step-by-step method is as accurate as the mathematical method, but the method described takes only some one or two per cent as much time as the mathematical method and with practise becomes as accurate as working conditions demand.

THE ideal method of finding the magnitudes of the current and voltage at points along an a-c. transmission line is the mathematical method; but anyone who has used that method knows that it consumes much time.

Because of the slowness of the mathematical method the straight forward step-by-step graphical method is preferred; but it also is slow and its results are inaccurate. The inaccuracy of the step-by-step method as ordinarily carried out is due partly to the mechanical difficulties of drafting and largely to the "rule and dividers" method generally employed for measuring and transferring the increments of current and voltage.

The present paper describes a novel method of drafting which makes drafting tools unnecessary, and by reducing the operations to a minimum, ensures both speed and accuracy.

Theory of the Method

A cable or other transmission line having given electrical constants is delivering alternating current of given frequency to a fixed load of given constants, and it is required to draw a complete vector diagram showing the current, the voltage at every point along the line, and their phase relationship. Fig. 1 gives an example of such a diagram. $O\,I_L$ is the vector of current taken by the load and $O\,V_L$ the vector of voltage at the load terminals. The lower curve is the locus of the extremities of the current vectors for points up to 30 mi. distant from the load end of the line, the distances in miles being

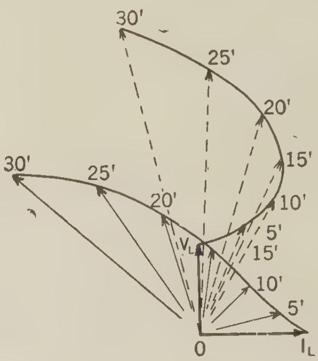


FIG. 1

marked as shown. For instance, the line drawn from 0 to 10 on the lower curve is the vector of current in the line at a point 10 mi. away from the load when the load current is $O\,I_L$. At this point in the line, the line voltage is shown by the vector 0–10′ the point 10′ being taken on the voltage (upper) locus. Thus the power

1. Asso. Prof. Electrical Engineer and Physics, State Univ. of New Mexico, Albuquerque.

2. See the *General Electric Review* of August, 1928.

factor of the load as measured at the load terminals is the cosine of the angle $V_L\,O\,I_L$, while the power factor measured at a point 10 mi. away from the load is the cosine of the angle 10–0–10′.

Step-by-step methods of building up such diagrams assume that over some short length of line—often one mile is short enough for practical accuracy—the value of the line voltage may be reckoned equal to the voltage at the end of that short length. For example, it would

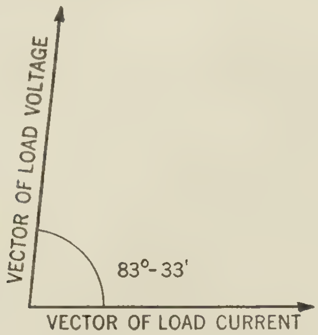


Fig. 2

be assumed that the line voltage one mile away from the load terminals is equal to the load voltage. With this preliminary assumption, the charging current and the leakage current in that one mile of line are calculated and added vectorially to the load current $O\,I_L$. The current vector thus obtained is multiplied by the impedance of one mile of line and the product represents the increment of voltage which has to be added vectorially to the load voltage in order to get the true line voltage one mile away from the load terminals. This value of the line voltage is supposed to act up to a point two miles from the load and the charging current and leakage current in the second mile can thus be calculated. The vector sum of these currents is now added vectorially to the current vector previously obtained and we thus find the line current two miles away from the load.

Succeeding increments of current and voltage are obtained in a similar way.

Proposed New Procedure

The chief novelty of the procedure lies in the use of celophane instead of paper for the vector diagrams. It is as transparent as clear glass, as thin as tissue paper and takes ink well. Its perfect transparency makes possible both speed and accuracy. A sheet of celophane of any convenient size may be used, but for accurate work it should be large, say, 30 in. square. For convenience in handling, the sheet should be glued to a frame made of stout drawing paper. Upon this sheet of celophane is drawn the vector diagram $V_L\,O\,I_L$ of the load, any convenient scale being used for current and voltage.

A large sheet of accurately ruled squared paper (millimeter squares are convenient) is fixed upon a drawing board and upon it are glued, at properly chosen angles, a pair of strips of celophane, each ruled with a clear straight line, marked off as a millimeter scale. Two triangles are drawn upon the squared paper, by aid of which the current and voltage vectors may be multiplied by the required constants for obtaining the increments of voltage and current.

The process of drawing the vector diagrams is best explained by reference to an actual example:

An overhead telephone line has a "go-and-return" resistance of 110 ohms per mile (that is to say the wire itself has a resistance of 55 ohms per mile) $r = 110$.

The go-and-return inductance per mile is $L = 0.0056$ henry.

The insulation resistance measured between one mile of "go" conductor and the corresponding mile of "return" conductor is $R = 0.08$ megohm.

The capacity between conductors per mile is $K = 0.0009\ \mu f$.

The load has a resistance of 120 ohms and an inductance of 0.13 henry and requires a current of 25 milliamperes.

The frequency of the a-c. being transmitted is 1300 cycles per second.

Load diagram (Fig. 2):

$2\,\pi\,f\,l = 2\,\pi \times 1300 \times 0.13 = 1061$ ohms reactance.

$z = \sqrt{120^2 + 1061^2} = 1065$ ohms impedance.

25 milliamperes will require a load potential difference of $0.025 \times 1065 = 26.63$ volts, and this potential difference will lead on the current by ($\tan^{-1} 1061/120 =$) 83 deg. – 33′.

Impedance per mile of line:

$X = 2\pi\,f\,L = 8160 \times 0.0056 = 45.7$ ohms,

hence,

$$Z = \sqrt{R^2 + X^2} = \sqrt{110^2 + 45.7^2} = 119 \text{ ohms.}$$

$\tan\phi = X/R = 45.7/110 = 0.416$, and $\phi = 22$ deg. 35′.

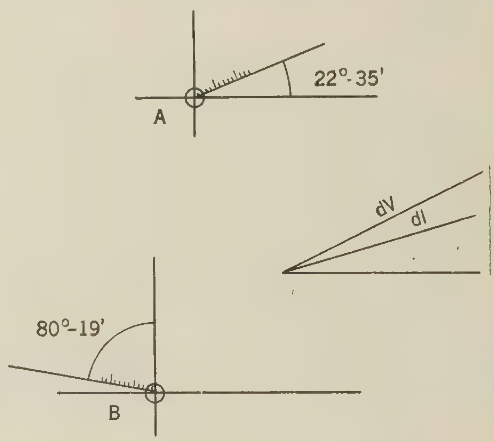


Fig. 3

Susceptance, leakage conductance and admittance per mile:

Susceptance, $B = 2\,\pi\,f\,C = 81\ \ 60 \times 9 \times 10^{-9} = 73.4 \times 10^{-6}$ mho.

Leakage conductance, $G = 1/(0.08 \times 10^6) = 12.5 \times 10^{-6}$ mho, and

Admittance, $Y = \sqrt{G^2 + B^2} = 74.5 \times 10^{-6}$ mho.

$\tan \phi = B/G = 5.86$, whence $\phi' = 80$ deg. 19′.

Hence, for one mile intervals we have:

Increment of voltage,

$$d\,V = ZI\ \underline{/22 \text{ deg. } 35'} = 1191\ \underline{/22 \text{ deg. } 35'}$$

Increment of current,

$$d\,I = Y\,V\ \underline{/80 \text{ deg. } 19'} = 0.075\,V\ \underline{/80 \text{ deg. } 19'}.$$

We mount a large sheet of millimeter paper on the drawing board—(Fig. 3)—and having made two strips of celophane, each about one inch by five inches and

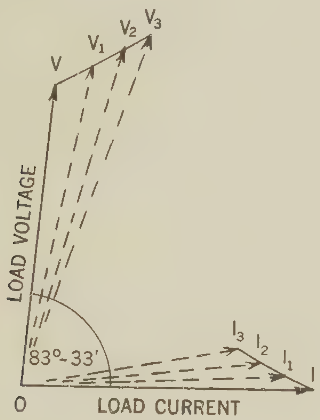


Fig. 4

with a central longitudinal line divided, a few centimeters of its length, into millimeter divisions, we fix one of these conveniently as at A in Fig. 3 so that the zero of its scale lies on a crossing of the squared paper while its center line makes the angle 22 deg. 35′ with the horizontal.

The other celophane strip is fixed, at say, B so that its center line makes an angle of 80 deg. 19′ with the vertical.

Choice of scale for load diagram:

The scales of volts and amperes may be chosen to suit the size of the diagram. In our example, we take 2.5 millimeters per volt and per milliampere. Then writing:

Magnitude of increment of voltage, $d\,V = 1191$, where I is in amperes, or $0.119\,I$, where I is in milliamperes, and magnitude of increment of current, $d\,I = 0.075\,V$ where V is in volts, we make use of two multiplying triangles, the one for finding $d\,V$ having a ratio of base to height of 1 to 0.119 and the other, for finding $d\,I$, having the ratio 1 to 0.75.

The base of the former should be at least as many centimeters long as the longest current vector is likely to be in milliamperes, while the base of the latter should be as many centimeters long as the longest voltage vector is likely to be in volts.

In our example, the two triangles were drawn upon one common base 30 cm. long.

For speed and ease of reading the vertical scales of the multiplying triangles may preferably be a multiple of the horizontal scales. In Fig. 3 the vertical scales are four times as open as the base scales, so that a vertical height of one centimeter means one milliampere or one volt.

Procedure

We superimpose the celophane sheet upon the sheet of squared paper, and so measure the length of $O\,I$ which we find to be 6.25 cm. as it represents 25 milliamperes to a scale of 2.5 mm. per milliampere .

Applying the line $O\,I$ to the base of the multiplying triangle, we read off a vertical height of 3.1 cm. from the point I to the hypotenuse of the 0.119 triangle. This gives $d\,V = 3.1$ cm. $= 3.1$ volts.

Shifting the celophane sheet into such a position that while $O\,I$ coincides with one of the horizontal lines of the squared paper the point V lies on the point A we put a dot of ink on the celophane at the point 3.1 volts (= 7.75 mm.) as seen on the scale A. Call this point V_1 (Fig. 4). Next measure the distance O to V_1 by laying the celophane sheet on the base of the multiplying triangle and measure the vertical height, 2.1 cm. (= 2.1 milliampere) to the 0.075 hypotenuse.

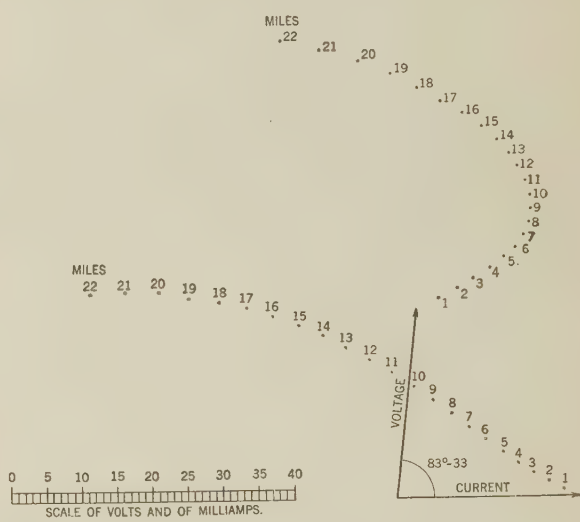


Fig. 5

Now move the celophane so that while $O\,V$ lies along a vertical line of the squared paper the point I falls on B and put an ink dot at the point 5.25 mm. (= 2.1 milliampere) along the B scale.

Continuing in this manner any number of successive points may be found. Fig. 5 takes the diagram to a distance of twenty-two miles from the load, one point being given at the end of each mile.

GAS LIGHTING IN PARIS

Manufactured gas—though more costly in France than in America—continues to dominate the field of illumination in Paris, according to George Reclus, Chief Engineer of the Societe du Gaz of the French capital, who was a visitor in Chicago recently.

The Parisian lighting system is comprised of 80 per cent of gas installations and 20 per cent electric, M. Reclus stated.—*Trans. I. E. S.*

Abridgment of

Some Problems in High-Voltage Cable Development

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and

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Introduction

A large amount of research work on high-voltage cable is being carried on throughout the country. It is generally recognized that duplication of effort can be reduced and general progress increased by comparison and common discussion of the independent investigations.

In order to encourage such cooperation, a few of the problems that are receiving attention in a manufacturer's laboratory are briefly presented herewith, effort being made to include a maximum amount of actual test data and a minimum amount of description and discussion.

Measurement of Dielectric Loss and Power Factor

In order to obtain increased sensitivity, the high-voltage bridge of Dawes and Hoover[1] has been installed in addition to the three-phase dynamometer method already available. The necessary high-voltage air condenser was constructed with three vertical plates, each 50 in. by 74 in.

The bridge was made applicable to three-phase measurements by development of the connection given in Fig. 1,† the only disadvantage of which is that a balance without the cable connected must be taken for each test voltage.

Determination of Insulation Quality

Considerable experimental work is in progress with the object of improving the quality of cable insulation. It is obvious that the reliability of the experimental indications is entirely limited by the reliability of the criterion of quality that is used. The most reliable test in common use for such purposes is the overvoltage life test on small cable samples, (often only 10 ft. long), at room temperature, with the cable ends in a cone of transformer oil.

Considerable experience with this test suggests that because of the great contrast between its conditions and those in service, it may not always give a true indication of relative quality. It is becoming an accepted fact that the cause of most premature failures in service is due fundamentally to the presence of shrinkage voids in the insulation that are formed by the shrinkage of the compound when it cools. While the service conditions, (extreme temperature changes with the insulation approaching a constant enclosing volume condition), encourage this void formation, the life test conditions (constant temperature with the insulation at the ends of the sample exposed to constant pressure) tend to discourage the void formation. Due to the different contraction and viscosity characteristics of the different compounds, this tendency may vary with different compounds.

Table I shows the results of life tests on cable saturated with three different compounds at each of several testing conditions. It is seen that the life is in general increased by conditions unfavorable to void formation and decreased by conditions favorable to void formation, the tendency varying with the compounds. In connection with the influence of conditions No. 2 on the cylinder oil, it has generally been found that when the life test is interrupted for several hours, the life will be increased, the cause being apparently the same in both cases—the application of sufficient heat to liquefy the compound and improve the void distribution. The relative independence of the resin compound to testing conditions also merits attention.

TABLE I
OVERVOLTAGE LIFE TESTS ON 10-FT. SAMPLES OF 1 x 2/0, 9/32 IN. WALL IN HRS. LIFE AT 65,000 VOLTS

Compound	Condition No. 1	Condition No. 2	Condition No. 3	Condition No. 4
70 per cent petrolatum B... 30 per cent transformer oil C	30	24	215	1.0
Cylinder oil.................	50	700	..	1.6
85 per cent cylinder oil...... 15 per cent resin...........	9	..	9.5	2.2

Each figure the average of three tests.
Condition No. 1—Tested at room temp. 25-30 deg. cent. with thin oil in ends
Condition No. 2—Tested after 300 hrs. at 25-35 deg. cent., otherwise same as No. 1
Condition No. 3—Tested at 40 deg. cent. ambient, otherwise same as No. 1
Condition No. 4—Sample ends sealed at room temp., with pothead compound, then sample plunged in ice and voltage applied. Final sheath temp. 3-6 deg. cent.

Investigation of the life test is in progress with the object of improving its reliability, possibly by some such modification as No. 4.

The ionization test or variation of power factor with voltage at room temperature has received considerable

*Both of the Simplex Wire & Cable Company, Boston, Mass.
1. See references end of paper.
† Figs. 1—7 and Table II omitted in this abridgment.
Presented at the Winter Convention of the A. I. E. E., New York, N. Y., Jan. 28-Feb. 1, 1929. Complete copies upon request.

attention as an indication of insulation quality. Fig. 2 shows a comparison between the life test on several cables and an ionization test made just before the life test. While differing in type, dimensions, impregnating procedure, and treatment previous to the life test, the cables were all impregnated with the same compound. The ionization tests were made at 24 deg. cent. and the life test at 20-26 deg. cent.

It is seen that 17 of the 19 samples in Fig. 2 indicate a fair relation between the ionization and life test, a flat power-factor curve in general corresponding to a long life. However, the two resaturated samples of Fig. 2 show up exceedingly well on ionization, but definitely deficient on life. Thus the life test and ionization test do not always agree.

Fig. 3 shows the room temperature power factor at 40 volts per mil versus the life on the same samples. It is evident that this power factor and the life test show a complete lack of agreement.

Air Resistance of Paper

One of the most important properties of the paper is its compactness or denseness. This is usually measured by timing the passage of a given volume of air through a definite area of the paper, under a known pressure, and is known as the air resistance of the paper.

Fig. 4 shows that the air resistance has a pronounced influence on the dielectric strength of the saturated paper in sheet form and that the influence is independent of the kind of fiber, kraft, or manila. The papers shown in Fig. 4 represent 12 different manutures and, therefore, should be representative.

Table II indicates that the paper air resistance also has a pronounced influence on the dielectric strength of the completed cable. Both cables of each pair were alike in all respects except the air resistance of the paper.

Fig. 5 shows that the air resistance has a marked influence on the penetration of the compound into the paper, the higher the former the slower the latter. The penetration rate of the compound is important to the manufacturer in its influence on the time necessary for saturation of the insulation.

Selection of Compound

As the power factor of the compound has a controlling influence on the power factor of the cable, the deterioration of the compound power factor with heating is of importance.

Without the presence of air, it is insignificant in comparison with the deterioration in the presence of air.

Fig. 6 shows the relative power-factor deterioration of some representative compounds in the presence of air. Each sample was aged in the same shape container so that the area exposed to the air was always the same. All containers were immersed in an oil bath. Natural air circulation through the oven was provided. The temperature distribution was found to be uniform within the bath. The curves show that there is material difference between compounds and that sometimes a blend of compound will show more deterioration than its separate constituents. While the compounds containing resin show more deterioration at first, they eventually show marked improvement.

As the formation of the voids that are so harmful to the quality of impregnated insulation is caused primarily by the contraction of the compound on cooling, the volume change of the compound with temperature is important. Fig. 7 shows this characteristic for a few typical compounds. It is seen that all the compounds are alike when in a liquid state, but that when they solidify, the volume change approximately doubles. Therefore on cooling from 50 to 25 deg. cent., a petrolatum should form more voids than a cylinder oil.

The viscosity of the compound below 50 deg. cent. is of great importance because of its great influence on the formation and distribution of the shrinkage voids[2] and on the drainage of the compound. Fig. 8 shows this property on some typical compounds. It is seen that the movement of a petrolatum through the insulation should decrease sooner and more abruptly with decreasing temperature than that of a cylinder oil. Therefore, the petrolatum should begin to form voids at a higher temperature than the cylinder oil.

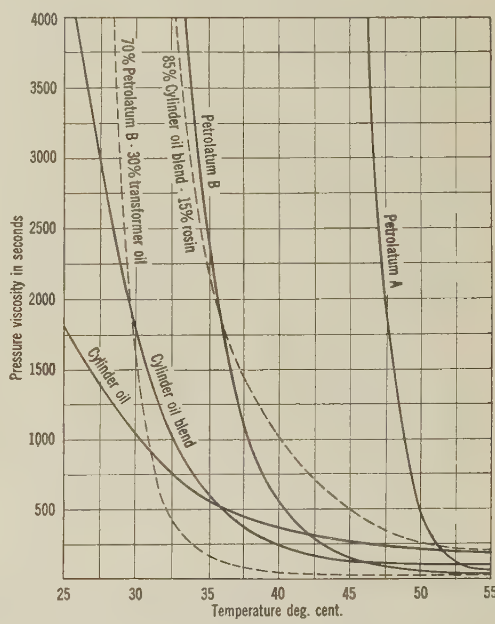


Fig. 8—Viscosity of Compounds

As no available viscosimeter was found for this range of viscosity, one was developed. It is substantially a weighted plunger sinking down into a cylinder slightly larger than the plunger, the cylinder being filled with the compound. The time for the total fall of the plunger is taken as the "pressure viscosity." This test has been found of considerable value in comparing compounds.

Because of greater simplicity in preparation and testing, miniature samples of insulation (thickness of 50 mils and less) are in considerable use for laboratory comparison of compounds. When tested immersed,

these samples represent almost ideal conditions for void elimination and when tested unimmersed, their failure is usually caused by expulsion of compound. Because of the extreme contrast between each of these conditions and service conditions, it is believed that results of this test are of doubtful value in comparing compounds.

It is now recognized that the formation of gas and X by compounds in the presence of corona (ionized voids) can only be eliminated by the development of a compound of sufficient chemical stability under these conditions. As the immediate development of such a compound is not promising, improved control of the void formation and distribution merits further consideration as a possible means of minimizing the dangerous gas formation and harmless X formation.

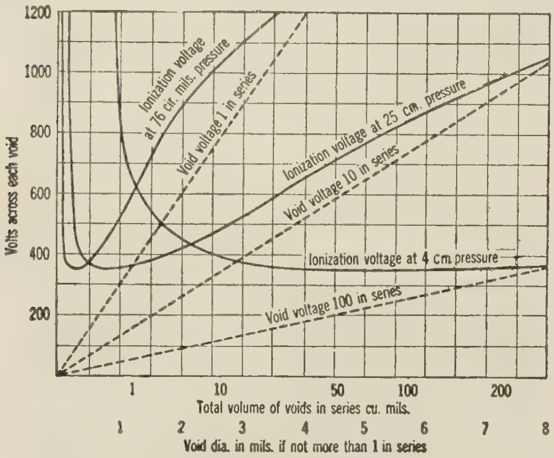


FIG. 9—INFLUENCE OF VOID SIZE PRESSURE AND ARRANGEMENT ON IONIZATION

Thickness of insulation—300 mils
Total voltage—30,000 volts
All voids the same size

MECHANISM OF VOID FORMATION AND IONIZATION

Under this heading are given some preliminary conceptions and test results that, while admittedly not conclusive, were thought of sufficient interest for subjection to general discussion.

A. Influence of Void Pressure and Size on Ionization. The upper solid curve in Fig. 9 shows the dielectric strength of air at atmospheric pressure. While the greater part of this curve was taken from an Institute paper,[3] the relations have been well established by several investigators independently. The application to this curve of Paschen's law (breakdown of air constant as long as the product of the gap length and absolute pressure is constant) gives the dielectric strength at other pressures as shown.

The dotted lines represent the voltage across each void in insulation 300 mils thick at 100 volts per mil total stress. When this voltage exceeds the ionization voltage (solid curves), the void will be ionized. The curves show that increase of void pressure and more complete distribution of voids (many small instead of few large voids) both tend to decrease the possibility of ionization.

B. Void Pressure Versus Air Content.

Let $V\,c$ = the volume of compound immediately surrounding a void, the compound that is subjected to a decreased pressure resulting from the formation of the void.

$V\,v$ = volume of the void.

$P\,v$ = pressure of the void in cm. absolute.

a = air content of the compound in fraction of compound volume, the air at atmospheric pressure.

Maximum solubility of the air in the compound = 13 per cent.

$V\,v$ = (total volume of air at pressure $P\,v$ separated from $V\,c$) = (total air content of $V\,c$ at pressure $P\,v$) – maximum dissolved air content of $V\,c$ at pressure

$$P\,v = \frac{76\,a\,V\,c}{P\,v} - .13\ V\,c \quad \text{or} \quad P\,v = \frac{76\,a\,V\,c}{V\,v + .13\,V\,c}$$

If $\dfrac{V\,c}{V\,v} = R$ Then $P\,v = \dfrac{76\,a\,R}{1 + .13\,R}$ (1)

$P\,p$ = (the pressure at which the air separates from the compound)

$$= \frac{76\,a}{0.13} \qquad (2)$$

Equations (1) and (2) indicate that $P\,v$ is dependent on a and R; as R increases, the value of $P\,v$ increases, approaching the critical pressure $P\,p$ as a limit. $P\,v$ is usually less than $P\,p$ because of the incomplete distribution of pressure through a stiffening compound.

If $\overline{V}$ = viscosity of the compound and K a proportionality factor

$$R = \frac{K}{V} \qquad (3)$$

When $R = 1000$ pressure distribution can be taken as reasonably complete as from (1) $P\,v$ = 99 per cent of $P\,p$.

If a pressure viscosity of 20 sec. (thin transformer oil) is taken as representing complete pressure distribution

$K = 1000 \times 20$ and (3) becomes $R = \dfrac{20000}{V}$, allowing the approximate determination of R for any viscosity.

The curve in Fig. 10 was plotted for a pressure viscosity of 145 by solving (3) for R, then solving (1) for $P\,v$ and obtaining the compounding total void volume possible without ionization from Fig. 9. The relation shown in Fig. 10 should be independent of the viscosity-

temperature characteristic of the compound because, other conditions being equal, the voids should begin to form at the same viscosity regardless of the temperature.

This curve is of considerable interest because it indicates that, in general, an air content in the neighborhood of 10 per cent is more desirable than one around 2 per cent.

C. Void Size Versus Moisture.

For the same total void volume, the size of each void is dependent on the distribution of the voids, many small or few large. It is evident that the more complete distribution (smaller voids) is desirable because it decreases the tendency to ionization.

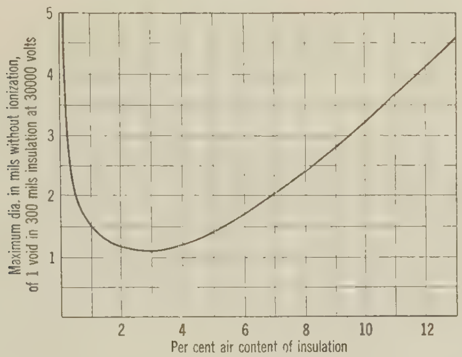


FIG. 10—INFLUENCE OF AIR CONTENT ON IONIZATION

Table III shows the results of some tests made with a glass tube approximately 9 in. long, of ¼ in. diameter, with a stop cock at each end. Each test was made by completely filling the tube between the stop cocks at 60 deg. cent., then closing the stop cocks and allowing the compound to cool to 25 deg. cent., when the resulting voids were counted. It will be noted that the dry compounds gave definitely less complete distribution (larger voids) than the compounds containing moisture.

This indication suggests an interesting advantage of compounds containing resin. Because of the well-known tendency of resin to evolve moisture when heated, such a compound is more liable to contain moisture in the cable and, therefore, to have smaller voids than a no-resin compound.

TABLE III
VOID DISTRIBUTION IN COMPOUNDS
Container 9 in. long x ¼ in. dia. Cooling range 60 to 25 deg. cent.

Teatment previous to test	Total number of voids in container	Relative average dia. of each void
Cylinder oil No. 1 + 15 per cent resin		
a—After 1 hr. at 120 deg. cent.	45	0.68 d_1
b—After the original mixing	116	0.50 d_1
c—*b* after drying	14	d_1
d—*c* after addition of moisture	3600	0.16 d_1
Cylinder oil No. 2		
a—Fresh from original container	320	0.4 d_2
b—*a* after drying	20	d_2
Petrolatum No. 1		
a—After drying	12	d_3
b—*a* after addition of moisture	3000	0.16 d_3
c—*b* after drying	14	0.96 d_3
Petrolatum No. 2 + 15 per cent resin		
a—After drying	6	d_4
b—After 15 hrs. at 200 deg. cent.	75	0.43 d_4

When an enclosed volume of compound shrinks, the molecules of the compound are torn apart at some point (their cohesion is overcome), and a void is formed there. As the shrinkage continues, this void increases in size. As the surface of the void enlarges, some expenditure of energy is necessary to rearrange the molecules at the boundary of the void and compound. As the void becomes larger, this expenditure of energy increases. When the energy necessary to enlarge the void becomes greater than the cohesion of the compound, molecules somewhere else in the compound will be torn apart and a new void formed. This would indicate that a decrease in cohesion should increase the number of voids and, therefore, decrease the size of each void. As the surface tension of water is materially less than that of the compounds, the presence of moisture in the compound may appreciably decrease its cohesion.

SUMMATION

1. Reliability of insulation quality determination is essential to satisfactory progress in high-voltage cable development. The most reliable test available at present for this purpose is the overvoltage life test, but there is some evidence that even this test may not always give a true indication of insulation quality. Efforts are being made to increase its reliability by causing failure on test, by exaggeration of the causes of failure in service, rather than by increase of the operating voltage alone.

2. While the ionization test is usually in fair agreement with the overvoltage life test as an indication of insulation quality, there are some instances, as that of a resaturated cable, where an indication of quality by the ionization test is not confirmed by the life test.

3. The air resistance of the paper has a material influence on the dielectric strength of the cable, regardless of whether the paper is kraft or manila.

4. While voltage tests on miniature samples of insulation are of considerable value along some lines, they are not believed to be a reliable basis for comparison of compounds.

5. The interdependence of the contraction-temperature and viscosity temperature characteristics of the compound in their controlling influence on the formation of voids should receive more general consideration.

6. Tentative indications are found that a decrease in air content of the insulation might increase the tendency to ionization because of the resulting decrease in void pressure.

7. Data are shown suggesting that ionization might be decreased by the presence of moisture in the insulation because of the resulting more complete void distribution and consequent smaller size of each void.

References

1. *Ionization Studies in Paper Insulated Cables—I*, A. I. E. E. TRANSACTIONS, 1926, Vol. XLV.

2. "Void Formation in Impregnated Paper Insulation," W. N. Eddy, *Electrical World*, April 7, 1928.

3. *1922 Developments in Auto-Valve Lightning Arresters*, by A. T. Atherton, A. I. E. E. TRANSACTIONS, 1923, Vol. XLII.

Abridgment of

Power Limit Tests

On Southeastern Power and Light Company's System

BY S. MURRAY JONES[1]
Associate, A. I. E. E.

and

ROBERT TREAT[2]
Member, A. I. E. E.

Synopsis.—*Calculations and tests on small models have indicated that power systems at or near the theoretical power limit could not be operated safely, since any slight disturbance would cause instability with the resultant separation of the power transmission system. Very often, tests on small models do not closely check the results obtained on the real system; therefore, as a result of certain troubles which occurred on the Southeastern Power & Light Company's system in 1925, apparently due to instability, it was decided to attempt to determine by actual tests the amounts of power which could be safely carried over certain transmission lines, and to compare the results with the calculated values. The General Electric Company offered to cooperate with the engineers of the Southeastern Power & Light Company in conducting such tests, and made them of further value by suggesting experimentation with certain schemes of high-speed excitation which could be applied to the generator excitation systems, in an effort to increase the maximum power limit which could safely be carried over the transmission lines.*

This paper presents the results of these tests and the conclusions to be drawn from them.

* * * * *

Introduction

During the Fall of 1925, there existed a very serious water shortage in Georgia and the Carolinas. The Alabama Power Company had a normal amount of water for that season and sufficient steam reserve capacity to be able to deliver power over its two tie lines into the Georgia and Carolina systems. The two tie lines which are the ones on which the tests were conducted were loaded to capacity.

There were some 300 miles of transmission line between the Alabama Power Company's plants and the Georgia Power Company's plants in Northeast Georgia.

It was necessary to set the relays to operate on values as low as 60,000 kv-a. This was close to the amounts of power which were being carried over each line during the times of peak load. Interruptions occurred in which both lines opened. Final analysis indicated that these lines were becoming unstable due to a reduction in voltage at one end or the other from short circuits external to the line.

After many discussions between the engineers of the General Electric Company and the Southeastern Power & Light Company, it was found desirable to make certain tests on these tie lines during the Spring of 1927.

Description of Tests

The object of the tests may be summarized as follows:

A. To obtain the maximum power limit of the south line (test line) as a check on the value predicated from calculations.

B. To determine the maximum carrying capacity of this line under normal operating conditions with Martin Dam connected to the Alabama Power System.

C. To determine the efficacy of various kinds of regulators including the standard regulators installed at the plant and of increased speeds of exciter build-up.

Three distinct kinds of tests were decided upon:

a. Steady-state pull-out between Martin Dam and the Georgia system, both with Martin Dam alone connected to the test line, and with Martin Dam and the test line connected to the Alabama system. When Martin Dam was connected to the Alabama system, the north line remained open.

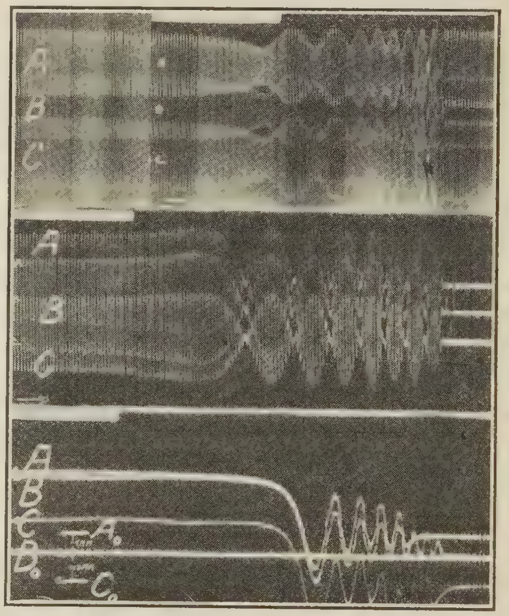


Fig. 3—Test No. 10. Steady-State Pull-Out of Test Line

Film No. 1—Line-to neutral volts on Martin Dam 110-kv. bus
Film No. 2—Current in test line
Film No. 4—Curve *A* Power, generator No. 2
Curve *B* Power in test line
Curve *C* Power, generator No. 3

b. Suddenly applied load by loading up the two tie lines in parallel and then tripping the north line to

1. Southeastern Engineering Company, Birmingham, Ala.
2. General Electric Company, Schenectady, N. Y.

Presented at the Regional Meeting of the Southern District No. 4 of the A. I. E. E., Atlanta, Ga., Oct. 29-31, 1928. Complete copies upon request.

determine how much could thereby be shifted to the test line without causing loss of synchronism.

c. Short circuit, obtained by closing a 110-kv. bus-tie oil circuit breaker at the high tension terminals of the Martin Dam transformers on a line-to-neutral short circuit of predetermined duration. The short circuit contained practically zero resistance. Tests involving short circuits were made with the north line open, but with Martin Dam both isolated and connected to the Alabama system.

Test Procedure

The test line was a 110,000-volt single circuit from the Martin Dam plant in Alabama to the Boulevard

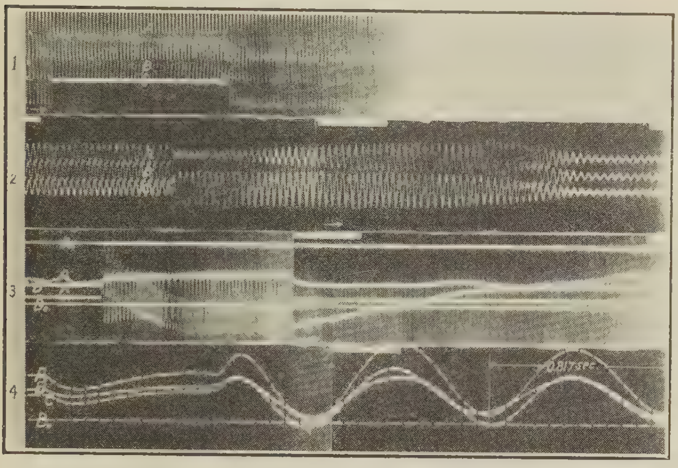


Fig. 6—Test No. 25A. Line-to-Ground Short-Circuit Test with Alabama System not Connected; Synchronism Maintained

Film No. 1—Line-to-neutral volts on Martin Dam 110-kv bus
Film No. 2—Current in test line
Film No. 3—Curve *A* Generator, slip-ring volts
Curve *B* Generator field current
Curve *C* Short-circuit current

Film No. 4—Curve *A* Power in test line
Curve *B* Power, generator No. 2
Curve *C* Power, generator No. 3

Substation near Atlanta, Georgia. This line is one of the important tie lines between the Alabama and Georgia systems.

For obtaining the test data, oscillographs and portable laboratory type indicating meters were located at Martin Dam, and graphic meters were installed at Gadsden, Newman, and Boulevard.

Continuous telephone communication was held between the plant superintendent at Martin Dam and the chief load dispatcher of the Alabama and Georgia systems. As the proper load was reached the oscillographs were started. If the test line failed to become unstable or appeared to reach instability too rapidly, the tests were repeated with a slightly larger or smaller load as the individual case dictated.

Curves and Tables of Results

From the oscillograph records it is possible to obtain a very comprehensive qualitative idea of the phenomena accompanying the disturbances. The oscillograms of

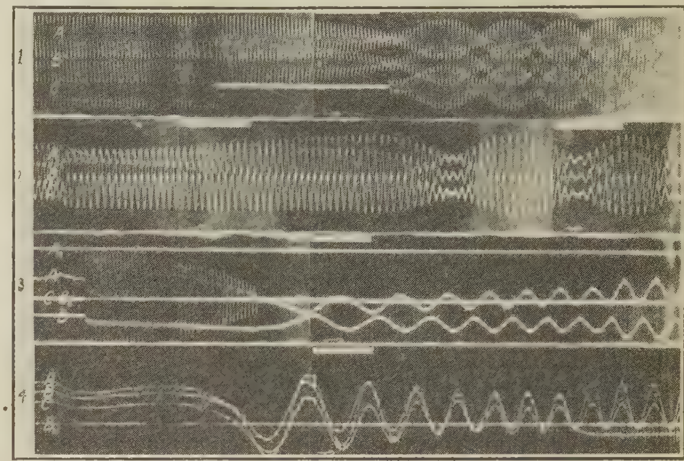


Fig. 7—Test No. 15B. Line-to-Ground Short Circuit Test with Alabama System Disconnected; Synchronism Lost

Film No. 1—Line-to-neutral volts on Martin Dam 110-kv. bus
Film No. 2—Current in test line
Film No. 3—Curve *A* Generator, slip-ring volts
Curve *B* Generator field current
Curve *C* Short circuit current

Film No. 4—Curve *A* Power in test line
Curve *B* Power, generator No. 2
Curve *C* Power, generator No. 3

power were obtained on a three-unit instrument, each unit of which consisted of a three-phase assembly of wattmeter elements.

TABLE I
STEADY-STATE POWER LIMIT WITH MARTIN DAM ALONE CONNECTED TO TEST LINE

Test No.	Excitation	Megawatts: Test	Megawatts: Calc. for same E_g and E_r	Ratio test to calc.	Test megawatts as percentage of maximum for line alone
8	Form Y—Std. exc.	93.6	82.3	1.137	73.6
9	Form K—24 exc.	90.6	80.6	1.124	73.7
10	Hand control	78.6	80.2	0.980	62.5
18	Form W—250 V/sec.[1]	104.5	90.9	1.150	79.8
21-A	Form Y—500 V/sec.[1]	97.4	75.4	1.292	80.5
21-B	Form W—500 V/sec.[1]	93.0	83.6	1.112	74.5

1. See text regarding thyratron grid control.

TABLE II
STEADY-STATE POWER LIMIT WITH ALABAMA POWER SYSTEM CONNECTED TO MARTIN DAM AND TEST LINE

Test No.	Megawatts: From test	Megawatts: Corrected to 110 kv.	Excitation	No. gen. used at Martin Dam
1	90	106	Hand control	2
2	104	112.3	Form Y std. exc.	2
3	102	110	Form W std. exc.	2
4	97.2	104.9	Form K—24 std. exc.	2
19	104.5	117.6	Form Y 250 V/sec.[1]	3
22	102.7	113.8	Form Y 500 V /sec.[1]	3

1. See text regarding thyratron grid control.

TABLE III

MAXIMUM POWER PRIOR TO LINE TO GROUND SHORT CIRCUIT THAT COULD BE CARRIED WITHOUT LOSS OF SYNCHRONISM

Test No.	No. Martin Dam machines	Estimated maximum power in kw. From tests	Estimated maximum power in kw. Corrected to 110 line kv.	Duration of short circuit in seconds	Volt-sec. rise during 1st. half swing of gen.[1]
		Alabama System not connected to test line			
11	2	28,000	31,450	0.857	−35.6
12	2	28,000	31,300	0.882	−34.9
14	2	29,000	32,400	0.832	−20.8
15	2	32,000	35,900	0.815	+12.7
16	2	32,000	36,100	0.807	− 2.0
17	2	32,000	36,600	0.807	− 0.7
25	2	39,500	40,300	0.825	+49.3
26	2	48,000	49,000	0.608	+31.2
27	2	55,000	56,000	0.433	+43.9
29	1	22,500	23,100	0.915	−35.0
31	1	23,000	23,700	0.907	−35.0
		Alabama System connected to test line			
24	2	55,000	58,500	0.682	+12.2
30	2	52,500	55,700	0.682	−16.7

1. See Appendix I.

TABLE IV

MAXIMUM POWER THAT COULD BE CARRIED OVER TEST LINE PRIOR TO TRIPPING NORTH LINE, WITHOUT LOSS OF SYNCHRONISM

Test No.	Line kv. Martin Dam	Line kv. Atlanta	Estimated maximum power in kv. From test	Estimated maximum power in kv. Corrected to 110 line kv.	Excitation
5	114.0	102.0	36,000	37,500	Form Y—Standard Exciter
6	113.5	102.0	36,000	37,600	Form K—24 Exciter
7	114.0	104.0	36,000	36,700	Hand control
20	112.0	105.0	36,000	37,000	Form Y—250 V/sec.[1]
23	110.0	102.0	35,000	37,600	Form Y—500 V/sec.[1]

1. See text regarding thyratron grid control.

Notes on Test Results

It should be borne in mind that the results herein presented were obtained on commercial power systems under actual conditions of operation, and mostly during times of peak load. This condition precluded the

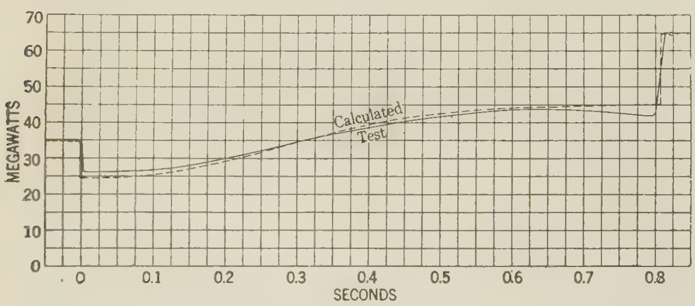


Fig. 10—Test No. 25A. Comparison of Calculated and Test Values of Instantaneous Power during Line-to-Neutral Short Circuit on Martin Dam High-Tension Bus

attainment of results of an accuracy approaching laboratory precision.

The relationship between generated and perceived power is presented in Fig. 13. It will be noted that the maximum power at the generator end occurs slightly after the systems have started to fall out of step and is somewhat greater than when the receiver is at the maximum. The absence of a second harmonic in these curves is owing to the method of calculation, and does not detract from their value for comparative purposes.

In certain of the tables, reference is made to control of the Martin Dam generators by types *W* and *Y* regulators. The type *W* regulator is that described by Messrs. R. E. Doherty,[3] C. A. Nickle, and R. M. Carothers[4] in papers presented at the St. Louis Regional

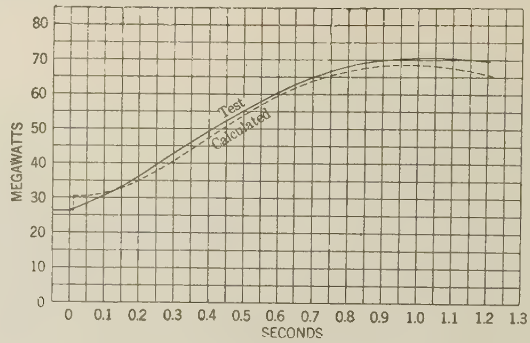


Fig. 12—Test No. 7A. Comparison of Test and Calculated Values of Instantaneous Power During Sudden Increase in Load by Tripping North Line

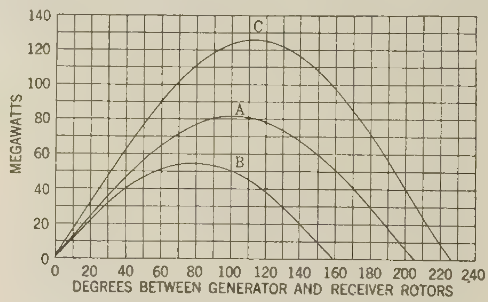


Fig. 13—Calculated Power Angle Curves for Test Line and Systems under Conditions of Test No. 10

Curve *A* Power at generator end of line under test conditions. The maximum of this curve is the value observed on all these tests

Curve *B* Power at load end of line under test conditions

Curve *C* Power at generator end of line if the power were limited only by the impedance of the test line

Meeting of the Institute in March 1928. The type *Y* is the commercial form thereof also referred to in those papers.

Some of the tests were made with the exciter fields supplied from a thyratron. The grid control for the thyratron was from d-c. batteries. Such control does not produce an exciter voltage decay at the same rate as the voltage rise. From the standpoint of aiding the new type of regulator to provide positive damping, it appears that the rate of decrease of exciter voltage should be approximately equal to the rate of increase.

3. July Quarterly Trans., p. 944.
4. July Quarterly Trans., p. 957.

For this reason, the new regulators probably could not show their maximum efficiencies.

It was possible to carry with fixed excitation amounts of power nearer the maximum theoretical limit than had been anticipated. The margin left for improvement owing to the different excitation systems proved to be considerably less than expected. Considering this, and the unfavorable condition as regards thyratron grid control, as well as the possible errors in the test results owing to the conditions under which they were made, no conclusive data were obtained on the efficiency of the new regulator, or of high-speed excitation.

Tests were made, with the short circuit maintained for differing times, and the results are shown graphically in Fig. 19. It is expected that similar results

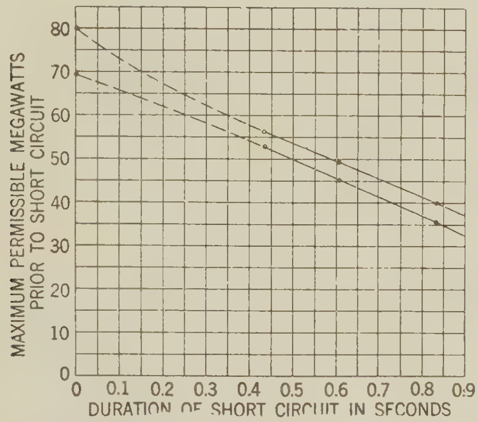


Fig. 19—Relation between Duration of Line-to-Neutral Short Circuit and Maximum Power That Can be Carried Prior to Short Circuit Without Losing Synchronism

would be obtained if it had been possible to try shorts with varying amounts of resistance and reactance simulating conditions when a fault occurs at some distance from the station, but they would not necessarily be comparable in magnitude.

Conclusions and Summary

The safe loading of the test line for operating conditions, considering that the north line may be tripped at any moment as a result of a disturbance on it, appears to be about 35,000 kw. From the standpoint of maintaining synchronism during short circuits on other circuits, the safe loading of the test line depends on the duration of the short circuit, and for a one-second duration appears to be about 35,000 kw.

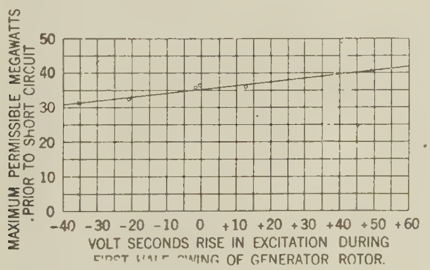


Fig. 20—Relation between Excitation and Maximum Power that can be Carried Prior to Line-to-Neutral Short Circuit of 0.83 Sec. Duration without Losing Synchronism

The gain in power which could be carried with the increased speeds of excitation used in these tests appears to be not great. Further consideration is given to the effect of excitation speeds in Appendix I, contributed by F. R. Longley, who has made most of the mathematical computations.

The use of a voltage regulator showed a small gain in steady-state power limit over the value with fixed excitation.

While the Alabama and the Georgia systems showed a fair degree of damping when made to oscillate with respect to each other by load increases, there was very little damping evidenced when the oscillation was between Martin Dam and either of the two systems. This would indicate the desirability of providing waterwheel generators with amortisseur windings.

A reduction in the duration of short circuits increases the amount of power which can be carried during a short circuit.

Information was secured concerning the equivalent

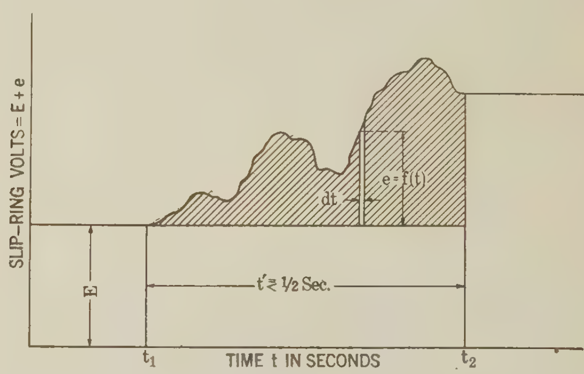


Fig. 21

constants of the system which permit very close mathematical checks on the results attained.

The authors desire to express their appreciation of the assistance rendered by the executives of the companies concerned, in granting permission to make the tests; to the operators, load dispatchers, maintenance crews, and engineers of the operating companies for whole-hearted cooperation in carrying out the tests; and to members of the Engineering Department of the General Electric Company for valuable assistance in working up the data, and for many pertinent suggestions as to methods of analysis and interpretation.

Appendix I

The Effect of Excitation upon the Maximum Power That Can Be Carried Through a Transient Disturbance

By F. R. Longley[6]
Associate, A. I. E. E.

An increase in rotor flux of the proper amount will

6. Electrical Engineer, General Electric Co., Schenectady, N. Y.

avoid the wild swings of the rotor which throws synchronous apparatus out of step following single-phase short circuits. The rise in flux must be obtained before the rotor reaches the maximum angle of its first swing, which usually occurs in approximately one-half a second. Let

e = change in slip ring volts (see Fig. 21)
i = rise in field current produced by e
t = time
L = inductance of field circuit
R = resistance of field circuit
ϕ = rise in field flux
k = a constant

The inductance of the fields of large alternators is so great that for periods of time less than half a second, the increased resistance drop, $i\,R$, is small when compared to the inductive drop, $L\frac{d\,i}{d\,t}$, and may be neglected in the formula:

$$e = L\frac{d\,i}{d\,t} + i\,R$$

so that

$$e \cong L\frac{d\,i}{d\,t}$$

$$i \cong \frac{1}{L}\int_{t_1}^{t_2} e\,d\,t$$

$$i = k\,\phi$$

and

$$\phi \cong \frac{1}{k\,L}\int_{t_1}^{t_2} e\,d\,t$$

The integral $\int_{t_1}^{t_2} e\,d\,t$ is the shaded area in Fig. 21 and is entirely independent of the shape of the volt–time curve. The area under the volt–time curve has the unit, volt–seconds. If the rise in volt–seconds is known at any moment, and the phenomenon has not lasted for more than half a second, then the rise in flux is immediately known, for the two are directly proportional.

The relation between volt–seconds and the transient stability limits at Martin Dam are shown in Fig. 20.

AN EASY METHOD OF APPROXIMATING THE SQUARE ROOT

The following description of a novel method of approximating square root has been contributed by C. H. Willis, Department of Electrical Engineering, Princeton University.

The frequent occurrence of the radical $\sqrt{a^2 \pm b^2}$ in electrical calculations makes the solution of this expression a matter of importance. The method described below for handling this expression provides a simple and easy manner of obtaining an approximate solution. If one of the numbers be three times as great as the other, the accuracy of the approximation will be greater than the accuracy of a direct calculation on a 10 in. slide rule.

The radical $\sqrt{a^2 \pm b^2}$ may be expanded by the binomial theorem into the infinite series;

$$\sqrt{a^2 \pm b^2} = a \pm \frac{b^2}{2\,a} \mp \frac{b^4}{8\,a^3} \pm \frac{b^6}{16\,a^5}$$

This series is very rapidly convergent if a be greater than b, and under this condition we may write,

$$\sqrt{a^2 \pm b^2} = a \pm \frac{b^2}{2\,a}$$

If we assume a circuit with a resistance of 153 ohms and a reactance of 11 ohms, we may obtain the impedance by inspection as;

$$Z = \sqrt{\overline{153}^2 + \overline{11}^2} = 153 + \frac{121}{306} = 153.4$$

The answer correct to three decimal places is 153.395

It is not always so easy to obtain the solution by inspection but the solution has been reduced to squaring one number and dividing by twice another, which is a considerable gain over the direct method.

If we assume a circuit whose impedance is 175 ohms and whose resistance is 14 ohms we may obtain the reactance by inspection as;

$$X = \sqrt{\overline{175}^2 - \overline{14}^2} = 175 - \frac{196}{350} = 174.4$$

The answer correct to three decimal places is 174.439

The approximation here would be much closer if the true value of the fraction were used rather than the value obtained by inspection.

This method is also very useful in obtaining irrational square roots. If we desire the square root of 190 this may be written as a perfect square plus or minus a remainder. Thus by inspection we have;

$$\sqrt{190} = \sqrt{196 - 6} = 14 - \frac{6}{28} = 13.8$$

The answer correct to three decimal places is 13.784.

The accuracy of this method of approximation increases rapidly as a increases in size with respect to b. When a is as great as $3\,b$ the error caused by using the approximation rather than the true value is less than 0.2 per cent. When a is less than $3\,b$ the approximation gives only a rough estimate, but if a is greater than $3\,b$ the approximation is more accurate than a direct calculation on a 10-in. slide rule, and it is much easier to obtain the approximate solution.

Institute and Related Activities

The A. I. E. E. Winter Convention

Comprehensive Program of Technical Sessions and Inspection Trips

A WELL rounded program of important technical sessions and enjoyable recreation is offered in the Winter Convention to be held in the Engineering Societies Building, New York, January 28 to February 1. Technical sessions, inspection trips, a lecture, a medal presentation, a dinner-dance and a smoker constitute the features of this attractive program which is outlined in further detail in following paragraphs.

Technical Sessions

The technical papers deal with some of the livest topics in electrical engineering. The principal subjects will be dielectrics, electrophysics, cables, transmission, lightning, circuit breakers, communication, induction motors, other electrical machinery, measuring instruments and electrical measurement of non-electrical quantities. Forty-two papers will be presented in nine sessions. Details are given under the program of events.

One especially interesting session will deal with a new type of circuit breaker which employs no oil and in which heavy currents are interrupted very quickly. This session will be held on Wednesday morning, January 30.

Inspection Trips

A large number of very interesting trips are being arranged. Wednesday afternoon, January 30, has been set aside for trips though several of the trips may be made at other times by prearrangement.

Tickets must be secured in advance for all trips before 4:00 p. m. on the afternoon preceding the day on which the trips will be made. Tickets may be obtained at the Inspection Trip desk. Reservations may be made by mail.

Tickets will be limited in number and all who wish to take trips should register and secure tickets at an early date.

Among the trips which are planned are the following:

Trips for Wednesday Afternoon

160,000-kw. turbo-generators. Hell Gate Generating Station, United Electric Light & Power Co.

Technical show at Bell Telephone Laboratories.

Demonstration of talking motion pictures and equipment and delayed transmission and band-pass filter circuits.

Western Electric Company cable plant at Kearny, N. J.

West Orange switching station, Hudson 132-kv. switching station and Kearny generating station of Public Service Electric & Gas Co.

Printing plant of the *Daily News*, Brooklyn.

Hunts Point gas plant, Consolidated Gas Company.

Harrison Lamp Works and Edison Illuminating Institute of General Electric Co.

New Diesel electric ferryboat.

Plant of the American Telephone & Telegraph Co.

Daily Trips

(10 a. m. and 2 p. m. starting Tuesday afternoon, except first trip as noted below)

Telephotography—Long Lines Department of the American Telephone & Telegraph Company

Demonstrations 10 a. m. and 2 p. m. Wednesday and at 10 a. m. Thursday and Friday.

Newark Meter Works of the Westinghouse Electric & Mfg. Co.

The Electrical Testing Laboratories.

East River generating station of New York Edison Co.

System operator's office at Waterside Station, New York Edison Co.

Hudson Avenue generating station with inspection of network unit, Brooklyn Edison Co. Research Laboratory, Brooklyn Edison Co.

Medal Presentation

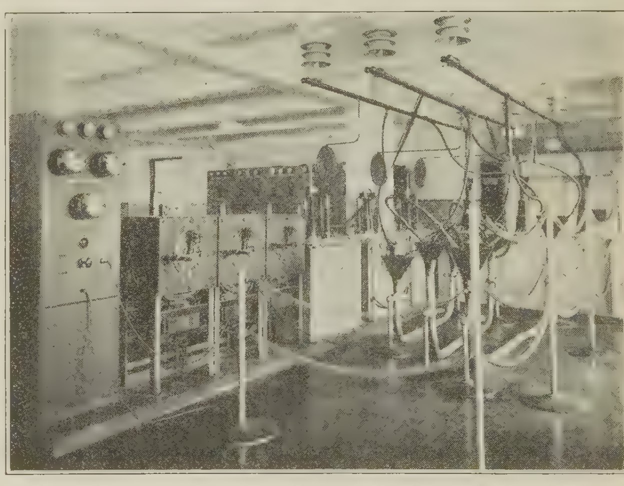
The presentation of the Edison Medal for achievement in electrical engineering is planned for Wednesday evening, January 30.

Dinner-Dance

A dinner-dance will be held in the Ballroom of the Hotel Astor on the evening of Thursday, January 31. This annual event, the Winter Convention Dinner-Dance, has proved so thoroughly enjoyable in the past that its popularity is assured. Besides an excellent dinner the committee promises the splendid music of the "Venetian Gondoliers." Tickets will be $6.00 per person. Reservations may be made for tables seating eight people.

Smoker

The Smoker to be held in the auditorium of the Engineering Societies Building on Tuesday evening, January 29, will be particularly attractive this year due to the type of program which has been arranged. The main feature of the evening will be a musical organization from one of the larger colleges: The humorist, Evan Davies, who is well known as the "Virginia Judge" through radio Station W. O. R., has been obtained. Other numbers equally as good are being arranged and will be announced later. The evening will be concluded with a buffet supper served by the well known caterer, Louis Sherry. Tickets will be $2.00.



High-Tension Cable Testing Facilities in Brooklyn Edison Research Laboratories
(Can be seen during Winter Convention)

Reduced Railroad Rates

Reduced rates for railroad transportation will be available under the certificate plan to members and guests who attend the Convention. Under this plan only half fare need be paid on the return trip over the same route provided 250 certificates are deposited by members at the Registration Desk. The rates apply to all members who attend the Convention and to dependent members of their families.

Each member or guest should obtain a certificate when purchasing his one-way ticket to New York. He should explain to the ticket agent that he wishes the certificate authorized by the passenger associations for the Winter Convention of the Institute.

On arriving at the Convention the certificate should be deposited at the Registration Desk. Here it will be held for validation by a railroad representative and if 250 certificates are validated, the validated certificate will later be returned to the owner. By presenting the validated certificate when buying a return ticket only half-fare will be charged.

East River Generating Station of New York Edison Company
(Can be seen during Winter Convention)

Local ticket agents should be consulted regarding conditions affecting this plan, as it applies only within certain dates depending on the territory.

Everyone whose one-way fare is over 66 cents *should get a certificate* whether or not he intends to use it. By neglecting to do so he may deprive others of considerable saving.

Register in Advance

Each member will save time for himself and the committee in charge if he will register in advance by mail.

Hotel Reservations

Reservations for hotel rooms should be made in advance in order to secure satisfactory accommodations. Members should write directly to the hotels which they prefer.

Committees

The general 1929 Winter Convention Committee is as follows: H. A. Kidder, Chairman; J. B. Bassett, H. P. Charlesworth, W. S. Gorsuch, G. L. Knight, E. B. Meyer, H. S. Sheppard, C. E. Stephens and R. H. Tapscott. The chairmen of the subcommittees are: *Entertainment*, J. B. Bassett; *Dinner-Dance*, C. R. Jones; *Inspection Trips*, F. Zogbaum, and *Smoker*, J. F. Fairman.

PROGRAM OF THE WINTER CONVENTION

Schedule of Events

Monday, January 28

Morning:	Registration and Committee Meetings
2:00 p. m.	Session on Dielectrics and Electrophysics

Tuesday, January 29

10:00 a. m.	Session on Cables
2:00 p. m.	Session on Transmission and Lightning
8:00 p. m.	Smoker and Entertainment

Wednesday, January 30

10:00 a. m.	Session on Protective Devices
2:00 p. m.	Inspection Trips
2:30 p. m.	Board of Directors' Meeting
8:30 p. m.	Medal presentations

Thursday, January 31

10:00 a. m.	Two Parallel Sessions (a) Communication (b) Induction Motors
2:00 p. m.	Session on Electrical Machinery
7:00 p. m.	Dinner-Dance

Friday, February 1

10:00 a. m.	Session on Electrical Measurement of Non-Electrical Quantities
2:00 p. m.	Session on Instruments and Measurements

Technical Sessions

Session on Dielectrics and Electrophysics

January 28, 2 p. m.

This session will contain four papers dealing with dielectric absorption, power factor and dielectric constant of viscous dielectrics, corona ellipses, and flux linkages. The papers are as follows:

Anomalous Conduction as a Cause of Dielectric Absorption, J. B. Whitehead and R. H. Marvin, Johns Hopkins University

Flux Linkages and Electromagnetic Induction in Closed Circuits, L. V. Bewley, General Electric Co.

Corona Ellipses, V. Karapetoff, Cornell University.

Power Factor and Dielectric Constant in Viscous Liquid Dielectrics, D. W. Kitchin, Simplex Wire & Cable Co.

Session on Cables

January 29, 10 a. m.

Five papers are scheduled for this session on the subjects of high-voltage cable development and research, ionization studies in paper-insulated cables, and elimination of losses and sheath voltages in single-conductor cables. The papers are as follows:

High-Tension Underground Cable Research and Development, G. B. Shanklin and G. M. McKay, General Electric Co.

Some Problems in High-Voltage Cable Development, E. W. Davis and W. N. Eddy, Simplex Wire and Cable Co.

Ionization Studies in Paper-Insulated Cables—II, C. L. Dawes, H. H. Reichard and P. H. Humphries, Harvard Engineering School

Reduction of Sheath Losses in Single-Conductor Cables, Herman Halperin and K. W. Miller, Commonwealth Edison Co.

Losses in Armored Single-Conductor Lead-Covered Cable, O. R. Schurig, H. P. Kuehni and F. H. Buller, General Electric Co.

Session on Transmission and Lightning

January 29, 2 p. m.

Lightning researches in the field and in the laboratory, and the theory of traveling electric waves will be the subjects covered in the five papers of this session. The papers are as follows:

A Graphical Theory of Traveling Electric Waves between Parallel Conductors, V. Karapetoff, Cornell University

Progress in Lightning Research in the Field and the Laboratory, F. W. Peek, Jr., General Electric Co.

1927 Lightning Experience on 132-Kv. Transmission Lines, Philip Sporn, American Gas & Electric Co.

Theoretical and Field Investigations of Lightning, C. L. Fortescue A. L. Atherton, and J. H. Cox, Westinghouse Electric & Mfg. Co.

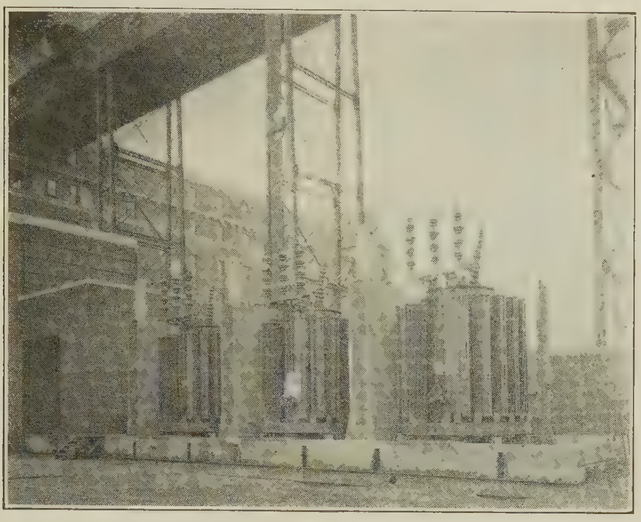
Protection of Transmission Lines from Interruption by Lightning, by 1927-28 Subcommittee of Power Transmission & Distribution Committee

Session on Protective Devices

January 30, 10 a. m.

A new type oil-less heavy-duty circuit breaker—its theory, construction and test—is the subject of three papers for this session, and the fourth paper will be on automatically reclosing high-speed d-c. breakers.

Theory of the Deion Circuit Breaker, Joseph Slepian, Westinghouse Electric & Mfg. Co.



Step-Up Transformers Feeding 132,000-Volt Cable at Hell Gate Station of United Electric Light & Power Company
(Can be seen during Winter Convention)

Structural Development of the Deion Circuit Breaker, C. R. Dickinson and B. P. Baker, Westinghouse Electric & Mfg. Co.

Field Tests on the Deion Circuit Breaker, B. G. Jamieson, Commonwealth Edison Co.

Automatic Reclosing High-Speed Circuit Breaker Feeder Equipment for D-C. Railway Service, A. E. Anderson, General Electric Co.

Session on Communication

January 31, 10 a. m.

Applications of radio in aviation, influence of moisture and impurities in textile insulations, application of purified textile insulation to central-office wiring, and vector representation of wave filters are the subjects for this session.

The Applications of Radio in Aviation, J. H. Dellinger, U. S. Bureau of Standards.

Influence of Moisture and Electrolytes upon Textiles as Insulators, R. R. Williams and E. J. Murphy, Bell Telephone Laboratories

Purified Textile Insulation for Telephone Central-Office Wiring, H. H. Glenn and E. B. Wood, Bell Telephone Laboratories

Vector Representation of Wave Filters, R. F. Mallina and O. Knacknuss, Victor Talking Machine Co.

Session on Induction Motors

January 31, 10 a. m.

The capacitor motor, low-starting-current induction motors, and calculation of no-load core losses are the subjects of the five papers planned for this session.

The Condenser Motor, B. F. Bailey, University of Michigan

The Fundamental Theory of the Capacitor Motor, H. C. Specht, Westinghouse Electric & Mfg. Co.

The Revolving-Field Theory of the Capacitor Motor, W. J. Morrill, General Electric Co.

Line-Start Induction Motors, C. J. Koch, General Electric Co.

Calculating No-Load Core Losses in Induction Motors, Thomas Spooner, Westinghouse Electric & Mfg. Co.

Session on Electrical Machinery

January 31, 2 p. m.

Five papers are planned for this session dealing with insulation tests on electrical machinery before and after placing in service, influence of temperature on commutators, transient conditions in electrical machines and transformers, and the two-reaction theory of synchronous machines.

Insulation Tests of Electrical Machinery Before and After Being Placed in Service, C. M. Gilt, Brooklyn Edison Company and B. L. Barns, Canadian General Electric Co.

Influence of Temperature on Large Commutator Operation, F. T. Hague and G. W. Penney, Westinghouse Electric & Mfg. Co.

Effect of Transient Voltages on Power-Transformer Design, K. K. Palueff, General Electric Co.

Transient Analysis of A-C. Machines, Yu H. Ku, Massachusetts Institute of Technology

Two-Reaction Theory of Synchronous Machines—Part I, R. H. Park, General Electric Co.

Session on Electrical Measurement of Non-Electrical Quantities

February 1, 10 a. m.

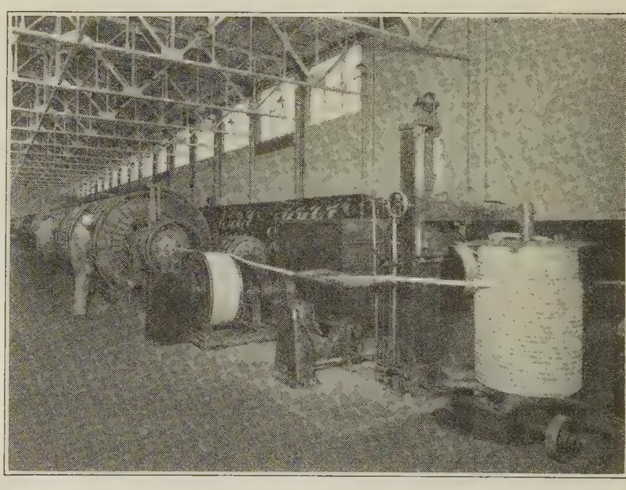
Magnetic analysis of materials, measurement of flow, use of the oscillograph in measuring non-electrical quantities, study of noises in electrical apparatus, and application of electricity to navigation are the subjects for this session.

Magnetic Analysis of Materials, R. L. Sanford, U. S. Bureau of Standards

Measurement of Flow by Use of Electrical Instruments, W. H. Pratt, General Electric Co.

Application of Electricity to Navigation, R. H. Marriott, Consulting Engineer

Use of the Oscillograph for Measuring Non-Electrical Quantities, D. F. Miner and W. B. Batten, Westinghouse Electric & Mfg. Co.



Manufacture of Cable in Plant of Western Electric Company
(Can be seen during Winter Convention)

Study of Noises in Electrical Apparatus, Thomas Spooner and J. P. Foltz, Westinghouse Electric & Mfg. Co.

Session on Instruments and Measurements

February 1, 2 p. m.

Totalizing meters, remote metering, high-accuracy current transformers, a 132-kv. shielded potentiometer, and a precision regulator for alternating voltage are the subjects of this session.

Telemetering, C. H. Linder, H. B. Rex and C. E. Stewart, General Electric Co.

Totalizing of Electric System Loads, P. M. Lincoln, Cornell University

A New High-Accuracy Current Transformer, M. S. Wilson, General Electric Co.

132-Kv. Shielded Potentiometer for Determining the Accuracy of Potential Transformers, C. T. Weller, General Electric Co.

A Precision Regulator for Alternating Voltage, H. M. Stoller and J. R. Power, Bell Telephone Laboratories.

FINAL STAGE IN MAKING LEAD-COVERED CABLE IN WESTERN ELECTRIC COMPANY PLANT
(Can be seen during Winter Convention)

Future Institute Meetings

During the year 1929 there will be held six Institute meetings, including three National Conventions and three Regional Meetings.

The three National Conventions will be the Winter Convention to be held January 28 to February 1 (see complete announcement elsewhere in this issue), the Summer Convention to be held in Swampscott, Mass., June 24-28, and the Pacific Coast Convention to be held in Los Angeles, September 3-6.

Regional meetings will be held in Cincinnati, March 20-22; in Dallas, May 7-9, and in Chicago, December 2-4.

More complete information regarding these meetings will be published in later issues of the JOURNAL.

Plans for World Engineering Congress, Tokio, Japan, are Actively Progressing

October—November 1929.

As previously announced, a World Engineering Congress will be held in Tokio, Japan, beginning October 29, 1929, and continuing about ten days, followed by trips to various places of engineering and scenic interest throughout Japan.

The object of the Congress is to effect an international exchange of the latest knowledge of the sciences and practises of engineering, and to bring together the leaders who are directing the trend of engineering activities, thereby initiating and promoting international cooperation and comprehension of engineers throughout the world.

A Committee on American Participation in the Congress was organized many months ago and various subcommittees on finance, technical program, transportation, entertainment, membership, etc., have been actively at work for several months. The interest already shown by engineers both in this country and abroad indicates a large attendance.

Dr. Masawa Kamo, Professor of Mechanical Engineering in the Imperial University at Tokio, and Chairman of the Organizing Committee of the Congress, was in New York early in December after visiting various countries of Europe in the interest of the Congress. The Committee on American Participation gave a dinner in his honor at the Engineers' Club, New York, on the evening of December 6, when reports were made by the various American committees, and Dr. Kamo gave an exceedingly interesting account of the plans being made in Japan for the visiting engineers and members of their families from foreign countries.

The Transportation Committee reported that the "official" ship will be the President Jackson, sailing from San Francisco October 11.

Dr. Kamo was told by Dr. Elmer A. Sperry, Chairman of the American Committee, that the attendance of a large delegation of American engineers was already assured.

A "second announcement" in the form of a booklet giving information regarding the program, and the excursions that will follow the technical sessions has recently been issued by authorities of the Congress in Japan. This booklet, together with application forms for membership in the Congress, transportation and hotel accommodations, etc., will be forwarded to any engineer applying to Mr. Maurice Holland, Executive Secretary of the American Committee, at 33 West 39th Street, New York, N. Y. Early application is desirable because of the limited number of those who may participate in the Congress as well as in some of the numerous trips which are to be taken.

International Conference on Large High-Voltage Electric Systems

Announcement has been received that the next session of this Conference, usually held biennially, will be held from June 6 to June 15, 1929, in Paris. This Conference was instituted in 1921, under the auspices of the International Electrotechnical Commission.

In the previous conferences of this large international organization, American representatives have taken a prominent part. The United States National Committee of the I. E. C. commends the Conference to American engineers, and requests members of the American Institute of Electrical Engineers and allied organizations who contemplate attending to forward their names promptly to the headquarters of the Institute, 33 West 39th Street New York, N. Y., for transmission to the United States National Committee of the I. E. C. Members who contemplate preparing papers for presentation at the Conference also are requested to send this information to Institute headquarters, at the same time apprising the General Secretary of the Conference, Monsieur J. Tribot Laspière, 25 Boulevard Malesherbes, Paris, France, of their intentions.

ASSEMBLING METERS IN WORKS OF WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY
(Can be seen during Winter Convention)

Edison Medal Awarded to Frank B. Jewett

AWARD TO BE MADE AT THE WINTER CONVENTION

The Edison Medal has been awarded by the Edison Medal Committee of the American Institute of Electrical Engineers to Dr. Frank B. Jewett, "for his contributions to the art of electrical communication." It is planned to present the medal to Dr. Jewett at a session of the coming Winter Convention of the Institute in New York, probably on Wednesday evening, January 30th.

The Edison Medal was founded by associates and friends of Mr. Thomas A. Edison, and is awarded annually for "meritorious achievement in electrical science, electrical engineering, or the electrical arts," by a committee consisting of twenty-four members of the American Institute of Electrical Engineers.

The following men have been recipients of the medal: Elihu Thomson, Frank J. Sprague, George Westinghouse, William Stanley, Charles F. Brush, Alexander Graham Bell, Nikola Tesla, John J. Carty, Benjamin G. Lamme, W. L. R. Emmet, Michael I. Pupin, Cummings C. Chesney, Robert A. Millikan, John W. Lieb, John White Howell, Harris J. Ryan, and William D. Coolidge.

Doctor F. B. Jewett

Dr. Frank B. Jewett, Vice-President, American Telephone and Telegraph Company, and President of Bell Telephone Laboratories, Inc., was born at Pasadena, California, September 5, 1879. He graduated in 1898 from Throop Polytechnic Institute (now the California Institute of Technology). He then took up graduate work at the University of Chicago under Professor A. A. Michelson, receiving his Doctor of Philosophy Degree in 1902. Later he was instructor in physics and electrical engineering at Massachusetts Institute of Technology, and in 1904 joined the staff of the American Telephone and Telegraph Company. He was given charge of the engineering research work, thus beginning his record of brilliant attainments in the telephone field. From 1908 to 1912, Dr. Jewett was Transmission and Protection Engineer, and under the direction of John J. Carty, then Chief Engineer, was given responsibility for working out the methods which led to the introduction in telephone service of phantom loading, loading of large gage and open-wire circuits, the practical use of telephone amplifiers and development of phantom duplex cables. In 1912 he became Assistant Chief Engineer of the Western Electric Company, and in 1916 Chief Engineer, having charge of the research laboratories and all engineering in connection with Western Electric manufacturing. Six years later he became Vice-President of the Western Electric Company.

In 1917 Dr. Jewett was commissioned Major in the Signal Corps, U. S. Reserves. He was promoted to the grade of Lieutenant Colonel, and for his brilliant service received the "Distinguished Service Medal." In 1925 he was elected Vice-President of the American Telephone and Telegraph Company in direct charge of Development and Research. At the same time, he was made President of the Bell Telephone Laboratories, Inc.

Dr. Jewett is a Fellow of the American Institute of Electrical Engineers, of which he was President during the year 1922-23. He has been a worker on many Institute committees, and is at present a member of the Public Policy Committee and the Committee on Code of Principles of Professional Conduct, and representative on the Electrical Advisory Committee of the American Standards Association, the U. S. National Committee of the International Electrotechnical Commission, and the Division of Engineering and Industrial Research of the National Research Council. Dr. Jewett is also a member of many other scientific and engineering organizations.

A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at Institute headquarters, New York, on Friday, December 7, 1928.

There were present: President R. F. Schuchardt, Chicago; Past President Bancroft Gherardi, New York; Vice-Presidents O. J. Ferguson, Lincoln, Neb., J. L. Beaver, Bethlehem, Pa., H. A. Kidder, New York; Directors M. M. Fowler, Chicago, E. C. Stone and F. J. Chesterman, Pittsburgh, Pa., C. E. Stephens, New York, I. E. Moultrop, Boston, H. C. Don Carlos, Toronto, F. C. Hanker, East Pittsburgh, E. B. Meyer, Newark. N. J., J. Allen Johnson, Niagara Falls, A. M. MacCutcheon, Cleveland; National Secretary, F. L. Hutchinson, New York.

The minutes of the Directors' meeting held October 18, 1928, were approved.

Announcement was made of the gift to the Institute, by Gillett & Johnston, of Croydon, England, bell founders of the Louvain Carillon, of a bell as a souvenir of the Carillon, and a resolution of acceptance and appreciation was adopted.

Action of the Executive Committee, under date of November 15, on applications for Student Enrolment, election to membership, and for transfer to higher grades, was ratified.

A report was presented of a meeting of the Board of Examiners held November 8, and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners, the following actions were taken: 190 Students were enrolled; 83 applicants were elected to the grade of Associate; 28 applicants were transferred to the grade of Member.

In accordance with Section 22 of the Constitution, relating to members of 35 years standing, Messrs. Frank E. Smith and E. S. Webster were added to the list of "Members for Life" by exemption from future payment of dues.

The Board ratified approval by the Finance Committee for payment of bills for the month of November amounting to $26,890.21.

In accordance with the procedure specified in the revised Constitution and By-laws, a resolution was adopted fixing the date

and place of the 1929 Annual Meeting of the Institute, to be held at Swampscott, Mass., on Tuesday, June 25, during the annual Summer Convention.

Upon the recommendation of Student Branch Counselor delegates at the Summer Convention in June, 1928, and of the Committee on Coordination of Institute Activities, a resolution was adopted authorizing an annual appropriation not to exceed $2000 for the purpose of mimeographing student papers presented at student conventions, not more than $250 to be expended by any one Geographical District in a calendar year, and all such mimeographing to be done under the immediate supervision of the Committee on Student Activities of the District in which the papers are to be presented.

Existing by-laws of the Institute were revised and new by-laws were added, covering various matters as recommended by committees and officers, all of which had been approved by the Law Committee. (The revised By-laws will be published in the 1929 Year Book, and any member who desires may obtain a pamphlet copy upon application to Institute headquarters.)

Upon the recommendation of the Standards Committee, Graphical Symbols for Telephone and Telegraph Use, prepared by a subcommittee of the Sectional Committee on Scientific and Engineering Abbreviations and Symbols, were approved for adoption as an Institute Standard and for transmission to the American Standards Association.

Mr. E. B. Craft was reappointed a representative of the Institute on the Library Board of the United Engineering Society, for the four-year term commencing January 1, 1929.

Mr. C. O. Bickelhaupt was appointed to serve on the Assembly of American Engineering Council, representing the Institute, for the two-year term commencing January 1, 1929, in place of Mr. A. G. Pierce, who had declined reappointment for that term.

Written and oral reports were received from A. I. E. E. Delegates F. A. Allner and E. C. Stone to the International Conference on Bituminous Coal held in Pittsburgh, November 19-24.

Other matters were discussed, reference to which may be found in this and future issues of the JOURNAL.

Scientific Conquests of 1928

At the January 9, 1929, meeting of the New York Electrical Society Doctor H. H. Sheldon, Chairman of the Department of Physics of Washington Square College, New York University, will give the third annual talk in review of progress in science and engineering during the preceding year. The exact title for the meeting will be "Scientific Conquests of 1928." The speaker will illustrate his lecture with a number of specially arranged demonstrations; among which will be:—the train that obeys its "master's voice," the use of an oxidizing agent as a fire extinguisher, the photoelectric cell as a traffic cop, a night watchman, etc. Each year this meeting, with its review of science, has proved of unusual interest to both the technical and non-technical man. The Society extends an invitation to members of the Institute to attend as its guests. Meeting will be held in the Engineering Auditorium, 29 West 39th St., New York at 8.15 p. m., Wednesday, January 9, 1929.

Polytechnic Institute Extends "Open-House" Invitation

On Friday, January 11, between the hours of 4:30 and 10:00 p. m. The Polytechnic Institute of Brooklyn will hold its annual "open house" reception to which it extends a cordial invitation to all.

At this time, the laboratories and shops of the Institute will be in operation and there will be student guides to accompany guests through the buildings. A moving picture "OPPORTUNITY," protraying engineering in the important fields of civil, electrical, mechanical and chemical operation will be presented.

Empire State Gas and Electric Association Electric Section Meets

The annual meeting of the Electric Section of the Empire State Gas and Electric Association will be held on January 10th and 11th at the United Engineering Society's building, 29 W. 39th Street, New York City.

Chairman A. R. Tremaine of the Associated Gas and Electric Companies and his Managing Committee have developed a very interesting program. For information on the details of the meeting, address C. H. B. Chapin, Secretary, Empire State Gas and Electric Association, Grand Central Terminal, New York City.

A. I. E. E. STANDARDS

A. I. E. E. STANDARDS APPROVED AS AMERICAN STANDARDS

Three additional A. I. E. E. Standards have just been approved as American Standards under the procedure of the American Standards Association. Those just approved are: No. 11, "Standards for Railway Motors;" No. 16, "Standards for Railway Control and Mine Locomotive Control Apparatus;" and No. 36, "Standards for Storage Batteries." The addition of this group makes a total of sixteen Standards accepted as American Standards.

Another group of Standards are being revised and will shortly come up for approval as American Standards. Of this group No. 5, "Direct Current Generators and Motors, etc;" No. 7, Alternators, Synchronous Motors, etc;" No. 9, "Induction Motors;" No. 10, "D-C. and A-C. Fractional Horsepower Motors." have been in Sectional Committee procedure for a long period and are about ready for submission to A. S. A. Another group of five are to be submitted to revision by Sectional Committees, not yet organized; they are: No. 19, "Oil Circuit Breakers;" No. 22, "Disconnecting and Horn Gap Switches;" No. 33, "Electrical Measuring Instruments;" No. 38, "Arc Welding Apparatus;" No. 39, "Resistance Welding Apparatus."

Switchboards and Switchgear: A Working Committee of the A. I. E. E. Standards Committee under the chairmanship of George Sutherland of the Queens Electric Light & Power Co. is making very rapid and satisfactory progress in the development of Institute Standards for Switchboards and Switchgear. It is expected they will shortly submit the results of their work to the Standards Committee for approval.

Graphical Symbols for Telephone and Telegraph Use: At the meeting of the Board of Directors of December 7 the "Report on Graphical Symbols for Telephone and Telegraph Use" was approved as an A. I. E. E. Standard. This report was developed by a subcommittee of the Sectional Committee on Scientific and Engineering Symbols and Abbreviations working under the procedure of the American Standards Association. This pamphlet will be published shortly by the Institute.

Hydraulic and Aeronautical Symbols: Reports of two subcommittees of the Sectional Committee on Scientific and Engineering Symbols and Abbreviations were approved by the Directors of the Institute at their meeting of October 18, 1928. When approval is obtained of the other four sponsors these two reports will be submitted to A. S. A. for final approval as American Standards. The Institute does not feel it necessary to publish these reports as they are entirely outside the electrical field.

Elmer A. Sperry now President of the A. S. M. E.

At the recent Annual Meeting of The American Society of Mechanical Engineers, held early in December 1928, the inauguration of Mr. Elmer A. Sperry, as the Society's new President took place.

As one of the Institute's Charter Members and because of his outstanding achievements in the scientific world, Mr. Sperry's history in the profession is already well-known to our readers.

A. I. E. E. Nominations

The National Nominating Committee of the Institute met at Institute Headquarters, New York, December 6, and selected a complete official ticket of candidates for the Institute offices that will become vacant August 1, 1929.

The committee consists of fifteen members, one selected by the executive committee of each of the ten Geographical Districts, and the remaining five elected by the Board of Directors from its own membership.

The following members of the committee were present: D. L. Brundige, Salt Lake City, Utah; W. P. Dobson, Toronto, Ont.; H. C. Don Carlos, Toronto, Ont.; O. J. Ferguson, Lincoln, Neb.; B. Gherardi, New York, N. Y.; F. B. Jewett, New York, N. Y.; J. E. Kearns, Chicago, Ill.; H. A. Kidder, New York, N. Y.; A. E. Knowlton, New Haven, Conn.; A. M. MacCutcheon, Cleveland, Ohio; E. B. Meyer, Newark, N. J.; N. W. Storer, East Pittsburgh, Pa.; L. F. Woolston, St. Louis, Mo.; G. J. Yundt, Atlanta, Ga.; and National Secretary F. L. Hutchinson. Mr. B. Gherardi was unanimously elected chairman of the committee.

The following is a list of the official candidates:

FOR PRESIDENT

Harold B. Smith, Professor of Electrical Engineering, Worcester Polytechnic Institute, Worcester, Mass.

FOR VICE-PRESIDENTS

Middle Eastern District: E. C. Stone, System Development Manager, Duquesne Light Company, Pittsburgh, Pa.

Southern District: W. S. Rodman, Professor of Electrical Engineering, University of Virginia, University, Va.

North Central District: Herbert S. Evans, Dean, College of Engineering, Professor of Electrical Engineering, University of Colorado, Boulder, Colo.

Pacific District: C. E. Fleager, Assistant Vice-President, Pacific Telephone & Telegraph Company, San Francisco, Calif.

Canadian District: C. E. Sisson, Transformer Engineer, Canadian General Electric Company, Ltd., Toronto, Ontario.

FOR DIRECTORS

J. E. Kearns, Electrical Engineer, General Electric Company, Chicago, Ill.

William S. Lee, Vice-President and Chief Engineer, Duke Power Company, Charlotte, N. C.

Charles E. Stephens, District Manager, Westinghouse Electric & Manufacturing Company, New York, N. Y.

FOR TREASURER

George A. Hamilton, Elizabeth, N. J., (re-nominated).

The Constitution and By-Laws of the Institute provide that the nominations made by the National Nominating Committee shall be published in the January issue of the Institute JOURNAL, and provision is made for independent nominations as indicated below:

CONSTITUTION

Sec. 31. Independent nominations may be made by a petition of twenty-five (25) or more members sent to the National Secretary when and as provided in the By-Laws; such petitions for the nomination of Vice-Presidents shall be signed only by members within the District concerned.

BY-LAWS

Sec. 22. Petitions proposing the names of candidates as independent nominations for the various offices to be filled at the ensuing election, in accordance with Article VI, Section 31 (Constitution), must be received by the Secretary of the National Nominating Committee not later than February 15 of each year, to be placed before that Committee for the inclusion in the ballot of such candidates as are eligible.

On the ballot prepared by the National Nominating Committee in accordance with Article VI of the Constitution and sent by the National Secretary to all qualified voters during the first week in March of each year, the names of the candidates shall be grouped alphabetically under the name of the office for which each is a candidate.

National Nominating Committee
By F. L. HUTCHINSON,
Secretary

Biographical Sketches of Candidates

FOR PRESIDENT

Harold B. Smith

Professor Harold B. Smith was born at Barre, Massachusetts, May 23, 1869. He was graduated from Cornell University with the degree of M. E. in Electrical Engineering in June, 1891, and remained as graduate student until December, 1891.

In January, 1892, he was appointed Professor of Electrical Engineering in charge of the department at the University of Arkansas. Resigning from this position in December, 1892, he became Head Designer and Electrical Engineer for the Elektron Manufacturing Company, Springfield, Mass. From September, 1893, to June, 1896, he was Director of the Department of Electrical Engineering at Purdue University. He has held his present position as Professor of Electrical Engineering and Director of the Department at Worcester Polytechnic Institute since 1896.

Professor Smith retained a connection with the Elektron Manufacturing Company as consulting engineer until 1902, and did consulting work for several other organizations at various times. Since 1905 he has served as a consulting engineer for the Westinghouse Electric and Manufacturing Company.

He was Chairman of the International Group, Jury of Awards in Electrical Engineering, at the St. Louis Exposition in 1904. During the years 1917-19 he was an associate member of the Naval Consulting Board and Consultant of the Special Board of the Navy on Anti-Submarine Work.

He has been a pioneer in the development of high-voltage power transmission systems and equipment, has carried on many researches involving advanced conceptions of dielectric phenomena and stress distribution, and holds numerous patents. He has contributed many papers to the transactions of the societies and other engineering publications.

Professor Smith's Institute activities are as follows: Associate 1891; Member 1901, Fellow 1913; Director 1920-24; Vice-President 1924-26; Chairman of Sections Committee 1924-27; and member at various times of the Coordination, Education, Electrophysics, Law, Instruments and Measurements, Sections, Student Branches, Edison Medal, Research, Meetings and Papers, and a number of special committees. He is at present Chairman of the Committee on Code of Principles of Professional Conduct.

His other memberships include the American Society of Mechanical Engineers (Member), Institution of Electrical Engineers (Great Britain), Society for the Promotion of Engineering Education, American Association fo the Advancement of Science, Fellow Sigma Xi, and Tau Beta Pi.

FOR VICE-PRESIDENTS

E. C. Stone

Edmund C. Stone was born in Charlestown, N. H., on December 8, 1882. He was graduated from Harvard University, receiving the degree of A. B. in 1904 and of S. B. in 1905. On leaving college Mr. Stone became an engineering apprentice at the works of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Penna., in 1905, and in the following year received an appointment as Designing Engineer in the Transformer Division of the Engineering Department.

In 1911 Mr. Stone joined the Alleghany County Light Company, which two years later became the Duquesne Light Company, with which company he has been associated ever since.

In 1913 he organized the System Operating Department of the Duquesne Light Company and remained System Operator until 1919, at which time he was appointed Assistant to the General

Manager. In 1922 he was made Planning Engineer in charge of planning the physical development of the power system.

On January 1, 1927, Mr. Stone was appointed Manager of System Developments in charge of system planning, engineering statistics, valuation work, and student engineering training, which position he now holds.

Mr. Stone has been active in Institute work. He was chairman of the Pittsburgh Section in 1922-23 and has been a Director since 1925, this term expiring in 1829. He has served as Chairman of the Protective Devices Committee, Chairman of the Standards Subcommittee of the Electrical Machinery Committee and as a member of other Institute Committees as follows: Executive, Automatic Stations, Power Transmission and Distribution, Special Committee on Technical Activities, Meetings and Papers, Power Generation, General Power Applications, and Law, being still a member of the last three. He has been on the Advisory Engineering Staff of the International Electrotechnical Commission for several years.

In 1925-26 Mr. Stone was Chairman of the Electrical Apparatus Committee, N. E. L. A., and, since July, 1927, has been Chairman of the Engineering National Section of the N. E. L. A. He has also contributed three important papers, dealing respectively with parallel operation of power plants, methods of power system grounding, and oil circuit breaker design and performance, to the TRANSACTIONS of the Institute.

During the past three years, Mr. Stone has been on the faculty of the School of Business Administration of the University of Pittsburgh and conducted a series of courses on the economics of public utilities. In 1927 he was appointed graduate lecturer in the Sheffield Scientific School of Yale University.

He is a member of the Harvard Club of Western Pennsylvania, Chamber of Commerce of Pittsburgh, Engineers Society of Western Pennsylvania and the Association of Iron & Steel Electrical Engineers.

W. S. Rodman

Walter Sheldon Rodman, Professor of Electrical Engineering in charge of the School of Electrical Engineering at the University of Virginia, was born in Wakefield, Rhode Island, on September 1, 1883. He was educated in the public grade and high-school of his native town and entered Rhode Island State College in the fall of 1900, graduating with the degree of B. S. in E. E. in June, 1904. For four years following graduation, he was engaged as Instructor in Mathematics, Physics, and Electrical Engineering at R. I. State College, receiving in 1907 the degree of M. S. in E. E., the first advanced degree ever awarded at the institution. The next two years were spent in graduate study at the Massachusetts Institute of Technology where, in 1909, the degree S. M. in E. E. was awarded, the last year there being spent as Saltonstall Fellow.

In the fall of 1910, appointment was made as Adjunct Professor of Electrical Engineering at the University of Virginia, followed in 1913 by an Associate Professorship and in 1917 by the Professorship, in which office service is still being rendered.

Mr. Rodman joined the Institute in 1907, was transferred to the grade of Member in 1912, and became a Fellow in 1928. He was one of the charter members of the Southern Virginia Section, serving continuously to date on its Executive Committee, and for the past three years has been Chairman of that Section. The University of Virginia Branch was organized by him in 1912, and since the office of Counselor was inaugurated, he has been active in that capacity at Virginia. He served one year as a member of the Committee on Student Branches. During the present year, he is a member of the National Sections Committee and of the Executive Committee of District No. 4.

His other memberships include Tau Beta Pi, Theta Tau, Phi Sigma Kappa, Pi Gamma Mu, Phi Kappa Phi, Phi Beta Kappa, Society for the Promotion of Engineering Education (Vice-President 1926-27), Illuminating Engineering Society, American Association of University Professors, and Fellow of the American Association for the Advancement of Science.

Herbert S. Evans

Herbert S. Evans, Dean of the College of Engineering and Head of the Department of Electrical Engineering of the University of Colorado, was born in Richardson County, Nebraska, on July 20, 1875.

After his early education in the local schools, he attended Morrill College, Kansas, for one year, 1891-1892, and then took up the study of Electrical Engineering at the University of Nebraska, where he received the B. S. (E. E.) degree in 1898, and the E. E. degree in 1900. While working toward his E. E. degree, he was in charge of the electrical work for the C. B. & Q. Railroad in Nebraska, continuing his work until 1901. At this time he was appointed instructor in electrical engineering at his Alma Mater, and was later promoted to adjunct professor. The honorary degree Doctor of Engineering was conferred upon him by the University of Nebraska in June, 1928.

In September, 1905, after a summer with the General Electric Company at Schenectady, New York, he was appointed Professor of Electrical Engineering and head of the department at the University of Colorado. This position he held until the fall of 1919, when, upon the resignation of Milo S. Ketchum, he was chosen Dean of the College of Engineering. As head of the College, Dean Evans came especially well qualified, for he had been acting dean during 1909-1910, and again during the trying war period of 1918-1919. At this time, too, he demonstrated unusual administrative ability as Director of all the S. A. T. C. activities at the University of Colorado.

Dean Evans joined the Institute in 1905 and was transferred to the grade of Member in 1909. He is a past chairman of the Denver Section.

In addition to the work of his immediate position, Dean Evans always has shown a broad, active interest in his profession and in state and local affairs. He is one of the outstanding citizens of Boulder, having served on the City Council since 1917, and being keenly interested and active in church work.

He was formerly chairman of one of the technical sections of the National Electric Light Association, and vice-president and member of the Council of the Society for the Promotion of Engineering Education. His other memberships include Sigma Xi, Tau Beta Pi, and Sigma Tau. He has contributed numerous articles to engineering publications.

C. E. Fleager

Clarence E. Fleager was born May 23, 1879, at Sheldon, Illinois, where he attended the public schools. He was graduated from the University of Illinois, Class of 1899, with the degree of B. S. in Electrical Engineering. On July 1, 1899, he entered telephone work at Chicago, Ill., and since has been continuously engaged in the telephone business.

After experience in nearly all branches of the telephone work, he was in 1910 appointed Division Plant Engineer, in 1917 Plant Engineer, in 1925 Chief Engineer, and in August, 1928, Assistant Vice-President, the position he now holds, all with The Pacific Telephone and Telegraph Company at San Francisco.

His experience with the telephone business has covered all phases of operation, engineering, and construction, and he has been in charge of numerous projects on the Pacific Coast. It was under his engineering supervision that the first transcontinental telephone line was opened for service in 1915. He has also taken an active part in the valuation and other work in connection with the regulation of the company's rates in the States of Washington, Oregon, and California from 1915 to date.

Mr. Fleager is a prominent member of the Engineers' Club of San Francisco, and has taken an active part in service and social clubs around San Francisco Bay.

He joined the Institute as an Associate in 1911 and in 1926 was transferred to the grade of Fellow. He has served on the

Executive Committee of the San Francisco Section and on the National Membership Committee.

Charles E. Sisson

Charles Everett Sisson was born in Ida, Ontario, Canada, October 25, 1879. He graduated from the University of Toronto in applied science and engineering in 1905.

Before his graduation, he had spent about one and one-half years in the Test Department of the Canadian General Electric Company, Ltd., and was employed by that company at Peterboro, Ontario, as Junior Designing Engineer from 1905 to 1911, and as Transformer Engineer in charge of transformer design during the following ten years. Since 1921 he has been Transformer Engineer with the same company at the Davenport Works, Toronto, and has been in charge of transformer, electric steam generator, and industrial electrical heating design. He is one of the leading designing engineers in Canada.

Mr, Sisson joined the Institute in 1919, and was transferred to to the grade of Member in 1928. He was Chairman of the Toronto Section during the administrative year 1927-28.

FOR DIRECTORS

J. E. Kearns

John Edward Kearns was born at Canajoharie, N. Y., November 30, 1879, and received his education at the Canajoharie High School, Clinton Liberal Institute, and the University of Michigan, taking a couse in electrical engineering at the latter.

Taking up engineering work with the General Electric Company, he was employed in drafting and testing 1902-3, design in the Direct-Current Engineering Department 1903-06, engineering and commercial work in the Power and Mining Department 1906-10, and in the Central Station Department 1910-15. Since 1915 he has served as Electrical Engineer in the Chicago office of the General Electric Company and has been in charge of special sales engineering work.

Mr. Kearns joined the Institute in 1907 and was transferred to the grade of Member in 1921. He is a Past Chairman and Secretary of the Chicago Section, and is at present Chairman of the National Membership Committee of the Institute.

He is a member of the National Electric Light Association, and has represented his company for many years as a member of the Technical Apparatus Committee of that Association. As such representative, he assisted materially in the preparation of some of the standards of the A. I. E. E. He was formerly a member of the Board of Directors of the Western Society of Engineers and President of the Michigan Engineers Club of Chicago, as well as Vice-President of the Chicago Alumni Association of the University of Michigan.

W. S. Lee

William States Lee was born in Lancaster, South Carolina, January 28, 1872, and was awarded the degree of C. E. by the Citadel, the Military College of South Carolina, in 1894.

Following his early engineering experience he was appointed Resident Engineer of the Anderson (S. C.) Light and Power Company in 1897; Resident Engineer of the Columbus (Ga.) Power Company in 1898, and Chief Engineer of the latter in March, 1902. In March, 1903, he was appointed Chief Engineer and in October of that year Vice-President and Chief Engineer of the Catawba Power Company, Charlotte, N. C. This Company was a subsidiary of the Southern Power Company and in 1905 he became Chief Engineer of the latter company. He later received the appointment of Vice-President and Chief Engineer, which position he held for about fifteen years. He is at present Vice-President and Chief Engineer of the Duke Power Company.

Among Mr. Lee's other connections the following should be included: President and Chief Engineer of the Piedmont and Northern Railway Company; Vice-President and Chief Engineer, Great Falls Power Company, Wateree Power Company, Western Carolina Power Company, Catawba Manufacturing and Electric Power Company, Duke Price Power Company, Ltd., Quebec Development Company, Ltd.; Director, American Cyanamid Company; and Trustee of the Duke Endowment. He has also engaged in practise as a Consulting Engineer, with an office in New York City.

He has been a pioneer in high voltage hydroelectric power development and transmission, and is inventor of the Lee Pin. His Institute activities are as follows: Associate 1904, Member 1907, Fellow 1913, Director 1911-14, and member for several years of the Committee on Power Transmission and Distribution, Standards Committee, and Committee on Power Generation, being still a member of the latter two.

Mr. Lee's other Society memberships include American Society of Mechanical Engineers, American Society of Civil Engineers, and the Engineering Institute of Canada.

C. E. Stephens

Charles E. Stephens, Northeastern District Manager, Westinghouse Electric & Manufacturing Company since April, 1925, has had a wide experience with the electrical industry since entering the Westinghouse organization when hardly more than a boy. His success has been one merited through hard work and diligent study both of the engineering and sales features of the business.

Mr. Stephens was born in Ferris, Texas, November 19, 1882, and attended the Ferris Institute. Becoming enthusiastic over the future of the electrical industry, he applied for a position with the Westinghouse Company in 1900, and he was placed in the Company's shops at East Pittsburgh as an apprentice. Here he gained a great amount of practical experience in electrical manufacturing practise, which he augmented by technical study. Mr. Stephens had the wisdom while on the apprentice course to follow the policy of securing work in as many different departments of the factory as possible, in order to broaden his knowledge.

Leaving the student work, Mr. Stephens finally gained an appointment in the Testing Department, from which he was later transferred to the Engineering Department. His work there was the design of molds for armatures and coils, for which his shop experience especially fitted him. After a short while he was assigned to motor insulation design and development.

After a relatively short time in this capacity, he was made Manager of the Arc Lighting Section of the Engineering Department, and then was promoted to the position of Illuminating Engineer of the General Engineering Department.

Leaving Engineering work, he was then made Manager of the Illuminating Section of the Sales Department, from which position he was transferred in 1917 to the New York office, as Manager of the Supply Department. Later he was made Manager of the Central Station division of the New York office, and in 1925 was made Manager of the district, the largest within the Westinghouse district sales divisions.

Mr. Stephens is now serving on the Board of Directors of the Institute and as a member of the Finance Committee. He is a past Vice-President of the Illuminating Engineering Society, and a member of several clubs and associations.

FOR TREASURER

George A. Hamilton

George Anson Hamilton, a charter member of the Institute, was born in Cleveland, Ohio, December 30, 1843. He early showed great interest in electricity.

In 1861, he bcame a messenger at Salem, Ohio, but two months later was made manager of the Atlantic and Great Western Railroad office at Ravenna. Illness forced him to relinquish this position in 1863, but upon his recovery he went to Pittsburgh as operator and manager of the Inland Company. In 1865, he became manager of the United States Telegraph Company's office at Franklin, Pa., but returned to Pittsburgh in 1866 as chief operator and circuit manager, and remained until 1873 when

the Western Union Telegraph Company absorbed his company.

As assistant to Professor Moses G. Farmer of Boston, who was engaged in the manufacture of general electrical apparatus and machinery, he received valuable experience and participated in many important experiments and investigations in telegraphy and other electrical developments during the period 1873-75. In 1875, he became assistant electrician of the Western Union Telegraph Company in New York City. He participated in the establishment and maintenance of the first quadruplex telegraph circuits, and carried out experiments perliminary to establishing the Wheatstone high-speed automatic system in this country.

In 1889, he accepted a position with the Western Electric Company, being given supervision and care of the department for the production of fine electrical instruments, which position he retained until his retirement in 1909.

Mr. Hamilton was the first Vice-President of the Institute (1884-86), and has been its National Treasurer since 1895, and a Fellow since 1913. He has for many years been a member of the Edison Medal and Executive Committees. His other memberships include Institution of Electrical Engineers (Great Britain), Société Francaise des Electriciens, Société Francaise de Physique, and Société Belge d'Astronomie.

American Engineering Council

LEGISLATIVE MEASURES OF INTEREST TO ENGINEERS

During the first few days in which Congress was in session the following bills of interest to engineers were introduced:

H. R. 14146 granting the consent of Congress to the county of Allegheny, Pa., to construct a bridge across the Monongahela River, in the city of Pittsburgh, Allegheny County, Pa. Introduced by Mr. Estep; to the Committee on Interstate and Foreign Commerce.

H. R. 14148 to amend the act of May 17, 1928, "An act to add certain lands to the Missoula National Forest, Mont." By Mr. Evans of Montana; to the Com. on Public Lands.

H. R. 14149 to provide a 5 year building program for the free public library system of the District of Columbia; By Mr. Gibson; to the Com. on the Dist. of Columbia.

H. R. 14158 to approve the action of the War Department in rendering relief to sufferers of the Mississippi River flood of 1927. By Mr. Morin; to the Com. on Military Affairs.

H. R. 14164 granting the consent of Congress to the city of Knoxville, Tenn. to construct a bridge across the Tennessee River at Henley Street in Knoxville, Knox County, Tenn. By Mr. Taylor; to Com. on Interstate and Foreign Commerce.

H. R. 14165 authorizing J. M. Leek & Co., their successors and assigns, to construct, maintain and operate a bridge across the Holston River at a point at or near Ruggles Ferry, Knox County, Tenn. By Mr. Taylor of Tenn.; to Com. on Interstate and Foreign Commerce.

H. R. 14166 to authorize an increase in the limit of cost of the experimental metal-clad airship now being built for the U. S. Navy. By Mr. Woodruff; to the Com. on Naval Affairs.

H. R. 14451 granting the consent of Congress to the County of Allegheny, Pa., to construct a bridge across the Ohio River between the city of Pittsburgh and the borough of McKees Rocks, State of Pennsylvania. By Mr. Campbell; to Com. on Interstate and Foreign Commerce.

H. R. 14453 to regulate interstate and foreign commerce in bituminous coal; provide for consolidations, mergers, and cooperative marketing; regulate the fuel supply of interstate carriers; require the licensing of corporations producing and shipping coal in interstate commerce; and to create a bituminous coal commission and for other purposes. By Mr. Casey; to Com. on Interstate and Foreign Commerce.

H. R. 14454 to provide for the establishment of a national employment system and for cooperation with the States in the promotion of such system, and to regulate the expenditure of moneys that shall be appropriated for such purposes. By Mr. Casey; to Com. on the Judiciary.

H. R. 14458 authorizing the Rio Grande del Norte Investment Co., its successors and assigns, to construct, maintain, and operate a bridge across the Rio Grande River at or near San Benito, Tex. By Mr. Garner of Texas; to Com. on Interstate and Foreign Commerce.

H. R. 14462 to amend the tariff act of 1922 by placing crude mineral oils on the dutiable list. By Mr. Howard of Oklahoma; to Com. on Ways and Means.

H. R. 14469 granting the consent of Congress to the county of Allegheny, Pa., to construct a bridge across the Youghiogheny River between the borough of Versailles and the village of Boston, in the township of Elizabeth, Allegheny County, Pa. By Mr. Kelly; to Com. on Interstate and Foreign Commerce.

H. R. 14471 to extend the time for the construction of a bridge across the Ohio River, between the North Side, Pittsburgh, and McKees Rocks Borough, in the county of Allegheny, in the Commonwealth of Pa. By Mr. Porter; to Com. on Interstate and Foreign Commerce.

H. R. 14472 to extend the time for construction of a bridge across the Mississippi River at or near the city of Vicksburg, Miss. By Mr. Collier; to Com. on Interstate and Foreign Commerce.

H. R. 14473 granting the consent of Congress to the city of Aurora, State of Illinois, to construct, maintain and operate a bridge across the Fox River within the City of Aurora, State of Illinois. By Mr. Reid; to Com. on Interstate and Foreign Commerce.

H. J. Res. 329 to create a commission for the revision of the shipping laws of the U. S. By Mr. LaGuardia; to Com. on Rules.

H. J. Res. 330 requesting the President to propose the calling of an international conference for the simplification of the calendar, or to accept, on behalf of the U. S., an invitation to participate in such a conference. By Mr. Porter; to Com. on Foreign Affairs.

H. R. 14665 to amend an act entitled "An act to provide that the U. S. shall aid the States in the construction of rural post roads and for other purposes" approved July 11, 1916, as amended and supplemented, and for other purposes. By Mr. Colton; to Com. on Roads.

H. R. 14673 to enable the Postmaster General to make contracts for the transportation of mails by air from island possessions of the U. S. to foreign countries and to the U. S. and between such island possessions and to authorize him to make contracts with private individuals and corporations for the conveyance of mails by air in foreign countries. By Mr. Kelly; to Com. on Post Offices and Post Roads.

H. R. 14674 authorizing the sale of surplus power developed under the Grand Valley reclamation project, Colorado. By Mr. Taylor; to Com. on Irrigation and Reclamation.

S. 4601 to amend the act entitled "An act to provide that the U. S. shall aid the States in the construction of rural post roads and for other purposes," approved July 11, 1916, as amended and supplemented, and for other purposes. By Mr. Oddie; to Com. on Post Offices and Post Roads.

S. 4602 to establish a Federal farm board to aid in the orderly marketing and in the control and disposition of the surplus of agricultural commodities in interstate and foreign commerce. By Mr. McNairy to Com. on Agriculture and Forestry.

S. 4659 to regulate the construction of bridges over navigable waters of the U. S. and for other purposes. By Mr. Brookhart; to Com. on Commerce.

S. 4660 to provide for the establishment of an 8 hour day for "yardmasters" of carriers. By Mr. Brookhart; to Com. on Interstate Commerce.

S. 4710 authorizing the sale of surplus power developed under the Grand Valley reclamation project, Colorado. By Mr. Phipps; to Com. on Irrigation and Reclamation.

S. 4712 to authorize the Secy. of War to grant a right of way to the Southern Pacific R. R. Co. across the Benicia Arsenal Military Reservation, Calif. By Mr. Shortridge; to Com. on Military Affairs.

S. J. Res. 173 requesting the President to propose the calling of an international conference for the simplification of the calendar, or to accept, on behalf of the U. S., an invitation to participate in such a conference. By Mr. Schall; to Com. on Foreign Relations.

S. 4675 to amend an act entitled "An act for the regulation of radio communications," approved Feb. 23, 1927, and for other purposes, was read twice by its title, referred to Com. on Interstate Commerce and ordered to be printed in the Record as follows:

Be it enacted, etc. That the act entitled "An Act for the regulation of radio communications" approved Feb. 23, 1927 and for other purposes, be amended by adding at the end of subsection C of section 4 the following:

Provided, That no broadcasting station licensed under the provisions of this act shall be permitted to use more than 10,000 watts of power for broadcasting, except for experimental purposes, and only after the hour of midnight and before 6 a. m. of any day for experimental purposes.

OPPOSES MOVEMENT TO TRANSFER GEODETIC WORK TO DEPARTMENT OF THE INTERIOR

Acting upon the report of its President, A. W. Berresford, legislation to transfer the geodetic work of the U. S. Coast and Geodetic Survery from the Department of Commerce to the Department of the Interior will be actively opposed by the American Engineering Council.

After a careful investigation of the situation, Mr. Berresford declared he could see little or no advantage and much potential disadvantage in such a proposal, since the work of the Geodetic Survey can be and is being coordinated with that of the Geological Survey so that the need of the latter is already being met. The work projected for the United States is only 60 per cent completed and if the country is to be duly served, it must continue with at least its present force. In fact the increasing demand for just this kind of work in all parts of the country, Mr. Berresford believes, evidences the importance of its continuance.

More About Louvain Memorial

Recently the four national societies of Civil, Mining, Mechanical and Electrical Engineers each received from Gillett & Johnston, makers of the memorial carillon and clock in the Louvain Library tower, a bell similar to the small bells of the carillon, suitably inscribed as a souvenir of the memorial.

The significance and usefulness of the Louvain carillon has been broadened by recent exchange of the following letters between the Committee on War Memorial to American Engineers and the University of Louvain.

24th, October, 1928.

My dear Monsignor Ladeuze,

Reflection since our return from Belgium has brought to mind a suggestion for the weaving of a strong thread into the fabric of our international friendship. We would not presume to indicate how and when your carillon should be used, but it would give much pleasure to engineers in America if on days which you might select the carillon might be played in memory also of the Belgian engineers who died in the service of their country during the Great War, 1914-1918.

Therefore, our Committee is considering a formal proposal to the University of Louvain and the Belgian Government that on your anniversary day, the 4th of August, and on such other days as you may select, at hours which you may choose, certain Belgian hymns of memorial and of victory would be played upon the Louvain carillon in honor and in memory of these Belgian engineers. In this way, we should like to join in our memorial the Belgian engineers with the engineers of the United States of America who gave their lives for the cause of Liberty in the Great War.

Sincerely yours,
EDWARD DEAN ADAMS, Chairman

Monsignor P. Ladeuze, Rector,
University of Louvain.

Louvain, November 13th, 1928.

My dear Mr. Adams,

Monsignor Ladeuze instructed me to answer your letter dated 24th October. The University of Louvain deems it a splendid and noble idea to have the carillon playing on certain days also in memory of the Belgian engineers who died in the service of our country in the Great War. It would, indeed, be weaving a strong thread in the fabric of our international friendship. Therefore, the University of Louvain is in full accordance with the proposal, and it seems a good thing that the carillon should play to the memory of the Belgian engineers who fell in the war, on the *4th of August*, anniversary of the invasion of Belgium, and also on the *11th of November*, Armistice Day.

This proposal is entirely in the line of what is said in the articles of the "Deed of Gift," and it covers admirably the Memorial, which the American Engineers erected at the University to be a token of everlasting friendship between them and the University of Louvain.

Believe me, my dear Dr. Adams, with kindest regards,

Yours affectionately,
L. VAN DER ESSEN, Sec., Univ.

PERSONAL MENTION

CHARLES S. RUFFNER, President of the Mohawk Power Corporation, was recently elected President of the Empire State Gas and Electric Association. Mr. Ruffner has been identified with electric light and power industries for almost thirty years.

R. A. GANTT, former General Manager of the Northern California and Nevada area, resigned his position October 1 to become Vice-President in charge of plant and engineering of the Postal Telegraph Cable Company, New York City.

H. U. HART, who has been General Manager and Chief Engineer of the Canadian Westinghouse Co., Ltd., has been appointed Vice-President of that organization. Mr. Hart joined the Institute in 1903 and has been a Fellow since 1913.

ROBERT P. KING, Past-Chairman of Springfield, Mass., Section, and for several years Works Engineer of Westinghouse Elec. & Mfg. Co. (East Springfield Works), has joined the engineering division of Du Pont Rayon Co., Buffalo, N. Y.

WILLIAM W. TEFFT, who has been Chief Engineer of the Commonwealth Power Corporation for the last five years, has resigned, to devote his entire time to his Consulting Engineering practise. He continues his residence and official headquarters in Jackson, Michigan, where he has resided for many years.

RICHARD I. WILSON has resigned from the Underground Transmission & Distribution Division of The Philadelphia Electric Company to accept a position as Sales Engineer with the Standard Underground Cable Co., a Division of the General Cable Corporation.

JAMES R. WERTH has just been appointed Commercial Manager for the State of Sao Paulo, Brazil, for The Empresas Electricas Brasileiras, at Sao Paulo, Brazil, an Electric Bond & Share property. He was formerly Head of the New Business Division of the Florida Power & Light Company, also an Electric Bond & Share property.

B. S. ROBINSON, formerly engineer for R. W. Cramer & Company, Inc., has been made Assistant Editor of the *Electrical World*. For the past 8 years Mr. Robinson has been with the Telegraph and Signal Department of the Pennsylvania Railroad and the same department of the Philadelphia Electric Company, with two years in the Engineers Corps of the United States Army.

Edwin W. Petty, recently with the Illinois Central Railroad as Assistant Engineer in connection with the Chicago Terminal Improvements, reports the completion of the design and partial operation of a new all-electric water pumping station for the City of Chicago. This station will be capable of pumping 160 million gallons of water per day and is the first station to be built for electrical operation from the start.

Obituary

Philip V. Bergen, Chief Electrical Inspector for the Bronx Gas and Electric Company, died at his home on November 12, 1928. Mr. Bergen was born at Westchester, N. Y., July 29, 1894, and was for eight years wth the General Public Utility El ectrical Engineering Work in the employ of the Bronx Gas and Electric Company, for which he was Electrical Inspector, Assistant to the Engineer of Distribution and in his last capacity of Chief Electrical Inspector. He joined the Institute in 1926 as an Associate.

Edward Preston Clifford, Vice-President of the Bell Telephone Laboratories, Inc. and a member of the Institute since 1911, died at his home, 850 Seventh Avenue, New York, N. Y., Sunday afternoon, December 16.

He was a native of New York City and his early education was acquired through school and private home tuition until his entry into the business world in 1892, when he joined the forces of the Western Electric Company. Through a series of promotions, he rose from office boy to cashier of the New York office; then chief clerk for the Chicago, Philadelphia, and New York branches; assistant manager of the New York Division; until, in 1911, he was made manager, with supervision over the Boston, Philadelphia, and Pittsburgh houses. In 1917 he was made eastern district manager. During the war, the engineering department was called upon to investigate many problems in connection with aircraft, submarine detection, artillery sound ranging, and radio, and to handle the multiplicity of commercial matters incident to this expansion, Mr. Clifford, on July 1, 1918, was called first as office manager, and a year later, as commercial manager. When the engineering department was incorporated in the Bell Telephone Laboratories, Mr. Clifford was elected vice-president in charge of the general staff, and in this capacity he built up the force of some 275 expert mechanics, at the same time caring for the maintenance of buildings aggregating 530,000 square feet of floor space. His ambition was to give his men, in addition to their own professional skill, an interest in and knowledge of the more technical side of the Laboratories work, thus to enable them to comprehend the language of the scientist and apply their own craftsmanship more effectively, relieving their associates of a vast burden of detail. His work included the administration of a budget of more than $15,000,000, and close relations with the American Telephone and Telegraph Company and the Western Electric Company.

Mr. Clifford was a member of the Telephone Pioneers of America, The Railroad Club, the American Yacht Club and the New York Athletic Club.

Nelson J. Young, Assistant Electrical Engineer of the Rochester Gas and Electric Company and an Associate of the Institute, died November 11, 1928 at Rochester, N. Y.

Born at Saugerties, New York, June 27, 1886, Mr. Young, after passing through public school, attended Pratt Institute and evening courses in Electrical and Mechanical Engineering at Columbia, Mechanics Institute of New York City and the Brooklyn Polytechnic Institute, as well as special laboratory courses given by the Brooklyn Edison Company. He was with the Western Electric Company from 1903 to 1905, first in the blue print room and then in the drafting room; then he joined the Duane Street office of the New York Edison Company as draftsman but was soon made a squad foreman, which position he held for four years. From 1914 to 1916, Mr. Young did some work for himself in another field and at the expiration of that time, entered the employ of the Detroit Edison Company as an electrical designer in charge of the electrical squad in the drafting room. A portion of 1917 was spent with J. A. Crowley Steel Company of Detroit, (through the courtesy of the Detroit Edison Company) installing two Greenwald-Dixon furnaces; then he joined the engineering department of the Electric Bond & Share Company, and for the latter part of the year 1918, he was with the Ordnance Department of the United States Government on the design of electrical equipment for the Aberdeen Proving Ground. He then was engaged by the United Gas and Electric Engineering Corporation as chief draftsman for three years and then as construction engineer in full charge in the field of installations of both electrical and mechanical apparatus in central stations and substations from the plants located at Leavenworth, Kansas, New Orleans, La., and Wilkesbarre, Pa. Through the United Gas and Electric Engineering Corporation, he then went to the Lockport Light Heat and Power Company as superintendent of Power and Construction. He joined his last company the early part of 1927. He was a member of the National Electric Light Association, the Lockport Lodge No. 67, F. and A. M., the Buffalo Consistory A. A. S. R. and the Junior Order of the United American Mechanics. Mr. Young had been an Associate of the Institute for four years.

Death of Mrs. Schuchardt

Mrs. Ada Briggs Schuchardt, wife of R. F. Schuchardt, President of the American Institute of Electrical Engineers and Electrical Engineer of the Commonwealth Edison Company, Chicago, died at the family home on Monday morning, December 24 of pneumonia. She had been ill only two days. On the previous Friday she had gone to a railroad station to meet her son, William, a freshman at Amherst, who was arriving home for the holiday season; on Saturday morning she was stricken with influenza, which developed rapidly into pneumonia.

Besides her husband and son, Mrs. Schuchardt is survived by a daughter, Betty. She was a member of a numbe: of women's clubs and had been active in civic affairs. Funeral services were private.

A. I. E. E. Section Activities

FUTURE SECTION MEETINGS

Cleveland

Characteristics and Limitations of Insulating Material for Power Cables, by E. M. Davis, Ass't Chief Elec. Engr., Simplex Wire and Cable Co. Electric League rooms, Hotel Statler. January 17.

Development in Power Machinery, by F. D. Newbury, Mgr., Power Engg. Dept., Westinghouse Electric & Mfg. Co. February 21.

Columbus

Aerial Photography, by Capt. A. W. Stevens, Chief Aerial Photo Branch, Wright Field. Joint Dinner Meeting with A. S. M. E. January 25.

Detroit-Ann Arbor

Research and Invention, by S. M. Kintner, Westinghouse Electric & Mfg. Co. January 15.

Indianapolis-Lafayette

Picture Transmission, by Dr. D. L. Ulrey, Westinghouse Electric & Mfg. Co. January 18

Pittsburgh

Our Opportunities for Service Through the Institute Section, by R. F. Schuchardt, National President, A. I. E. E. Dinner meeting. January 8.

The Extinction of an A-C. Arc, by Dr. Joseph Slepian, Consulting Engr., Westinghouse Electric & Mfg. Co. Dinner meeting. February 12.

Pittsfield

Mussolini and European Politics, by Dr. Bruno Roselli. Masonic Temple. January 8.

Transmission Line Stability, or Electrotherapeutics. Subject and speaker to be announced later. To be held at The Tally-Ho. January 22.

Portland

Electric Welding of Buildings and Bridges, by F. C. McKibben, Consulting Engr., General Electric Co. January 28.

San Francisco

Structural Steel Welding, by F. P. McKibben, General Electric Co. January 25.

Seattle

Address by an engineer of the American Telephone & Telegraph Co. January 15.

Welding of Steel Buildings and Bridges, by F. P. McKibben, Consulting Engr., Black Gap, Pa. February 12.

Sharon

Aviation Today, an Outline of Its Commercial, Military and Naval Aspects, by Lieut-Commander Bruce G. Leighton, Wright Aeronautical Corporation. Moving picture—"The Baron Shiba." January 15.

The Role of Physics in Industry, by L. O. Grondahl, Director of Research, Union Switch & Signal Co. February 5.

Vancouver

Students' Night. University of British Columbia Students. February 5.

Washington

Regular Meeting. January 8.

Automatic Train Control, by W. H. Reichard, Consulting Elec. Engr., General Railway Signal Co. February 12.

PAST SECTION MEETINGS

Akron

Dirigible Construction and Operation, by V. R. Jacobs, Ass't. Mgr., Aeronautics Dept., Goodyear Tire and Rubber Co. Film, entitled "Driving the Longest Railroad Tunnel in the Western Hemisphere." A dinner preceded the meeting. November 9. Attendance 90.

Boston

Practical and Simple Theories of Dielectric Action, by C. L. Kasson, Boston Edison Co. After presentation of the paper the Edison Company's laboratories were open for inspection and demonstrations were given. A dinner preceded the meeting. November 8. Attendance 79.

The Mastery of Lightning, by F. W. Peek, Jr., General Electric Co. Illustrated with slides. A buffet supper preceded the meeting. December 4. Attendance 215.

Chicago

Chicago World's Fair—Why, Where and When, by C. S. Peterson, Vice-President, Chicago World's Fair, and

Making Sound Visible and Light Audible, by J. B. Taylor, Consulting Engineer, General Electric Co. Illustrated with slides and demonstration. Joint meeting with Electrical Section, W. S. E., preceded by a dinner. November 19. Attendance 600.

Cincinnati

Research and Invention, by Thomas Spooner, Research Engr., Westinghouse Electric & Mfg. Co. November 15. Attendance 60.

Cleveland

Making Sound Visible and Light Audible, by J. B. Taylor, General Electric Co. Demonstrated. A dinner preceded the meeting. November 15. Attendance 145.

Connecticut

Remote Control, by J. L. McCoy, Westinghouse Electric & Mfg. Co. November 13. Attendance 400.

Dallas

Application of Electricity to the Oil Industry, by H. E. Dralle General Engr., Westinghouse Electric & Mfg. Co. Illustrated. November 19. Attendance 52.

Denver

Scientific Discoveries and Experiences in the Gobi Desert of Asia, by Dr. C. P. Berkey, Professor of Geology, Columbia University. Illustrated with slides. Meeting preceded by a dinner. November 9. Attendance 71.

Industrial Motors and Control, by H. B. Berkeley, Engr., Westinghouse Electric & Mfg. Co. Illustrated by slides and blackboard sketches. Meeting preceded by a dinner. December 4. Attendance 24.

Detroit-Ann Arbor

The Importance of High-Voltage Measurements, by Wm. W. Tefft, Vice-President and Chief Engr., Commonwealth Power Corp.;

Methods of Measuring Extra High Voltages, by Prof. C. Francis Harding, Head, School of Elec. Engg., Purdue University;

A New Automatic Recording Cathode-Ray Oscillograph, by R. H. George, Research Associate, Elec. Division of Engg., Purdue University, and

Installation and Use of the Automatic Recording Cathode-Ray Oscillograph for Recording Lightning Transients on the Consumers Power Company System, by J. R. Eaton, Transmission Engr., Consumers Power Co. Illustrated with slides. The meeting was preceded by a banquet with music and entertainment and followed by a demonstration of the cathode-ray oscillograph. An inspection trip to the Blackstone Substation and the Electrical Laboratory of the Consumers Power Company and the radio manufacturing plant of the Sparks-Withington Company was arranged during the afternoon for the delegation of students from the University and State College who attended the meeting. November 13. Attendance 265.

Electric Melting, by E. L. Crosby, President, Detroit Electric Furnace Co. Film, "Electric Heating in Industry, Industrial Heating Subcommittee, Power Committee of the National Electric Light Association." December 11. Attendance 75.

Erie

Silk, by Mrs. Carolyn R. Lewis, Publicity Director, H. R. Mallinson Co. Following the talk motion pictures of the silk industry were shown. November 20. Attendance 150.

Fort Wayne

Weather and Weather Forecasting, by E. L. Hardy, United States Weather Bureau. November 22. Attendance 60.

Houston

Repairs to Electrical Machinery, by A. C. Kater, President, Houston Armature Works. The meeting was preceded by a dinner. November 14. Attendance 33.

Indianapolis-Lafayette

The Trend of Motor Application in Industry, by W. A. Black, Chief Engr., Fairbanks, Morse & Co., and

Modern Control for Industrial Motors, by E. C. W. Johnson, General Electric Co. A smoker followed the technical session. November 9. Attendance 40.

Electrical Measuring Instruments. Discussion led by P. A. Westburg, Westburg Engineering Co. 5 reels of motion pictures. Social get-together and smoker followed. December 7. Attendance 42.

Ithaca

Transformers, by L. H. Hill, American Brown-Boveri Elec. Corp. Illustrated. December 7. Attendance 76.

Kansas City

The Engineer in Promotional Work, by J. L. Harrington, Consulting Engr., and

Large Inter-Connecting Systems, by R. C. Bergvall, Consulting Engr., Westinghouse Electric & Mfg. Co. Illustrated with slides. November 13. Attendance 200.

The Report on the Street Railway Situation, by P. C. Groner, President, Kansas City Public Service Co., and

Mr. Televox, the Electrical Man, by J. L. McCoy, Engr., Westinghouse Electric & Mfg. Co. Demonstration. November 30. Attendance 165.

Lehigh Valley

The Property Right of the Engineer, by M. J. Martin, Attorney, and

Train Control, by C. S. Williams, D. L. & W. Railroad. In the afternoon an inspection trip was taken through the shops of the D. L. & W. A dinner also preceded the meeting. October 19. Attendance 98.

Anthracite Problems, by E. H. Suender, Vice-President, Madeira, Hill & Co., and

The Lightning Problem and Lightning Research, by J. H. Cox, Westinghouse Electric & Mfg. Co. A dinner preceded the meeting. Joint with Engineers Society of Northeastern Pennsylvania. November 16. Attendance 190.

Inspection trip, through the courtesy of Madeira, Hill & Co., to their Colonial Breaker at Mount Carmel, Pa. November 17. Attendance 20.

Los Angeles

Recent Research Work in Aeronautics, by Prof. A. A. Merrill, Instructor in Experimental Aeronautics, California Institute of Technology. The meeting was preceded by a dinner. October 30. Attendance 122.

Louisville

Mr. Televox, the Electrical Man, by J. L. McCoy. Westinghouse Electric & Mfg. Co. November 23. Attendance 62.

Lynn

Under the Northern Lights, by Capt. D. B. MacMillan. Illustrated with slides and moving pictures. Ladies Night. November 20. Attendance 1300.

Financial Engineering and Construction Problems Encountered in a Large Project. Engineering Economics, by C. W. Kellogg; President, Public Service Corp.; *Hydraulic Problems at Conowingo*, by H. A. Hageman, Chief Hydraulic Engr., Stone & Webster; *Electrical Design of Conowingo*, by R. H. Barclay, Elec. Engr., Stone & Webster; and *Construction Problems at Conowingo*, by W. L. Lock, Vice-President, Stone & Webster. November 28. Attendance 180.

Mexico

Luncheon Meeting. October 5. Attendance 13.

Annual Banquet. Among the speakers were: P. M. McCullough, Chairman; Capt. H. Cross, Equipment Engr., Mexican Telephone Co.; H. G. Michell, Supt. of Distribution, Mexican Light & Pr. Co.; C. DeLima, Radio Dept., Int. Westinghouse Co.; V. Souza, Souza & Rincon Gallardo Co.; E. F. Lopez, Toastmaster. October 20. Attendance 40.

The Telephone in the Railways, by B. E. Arias, Head, Dept. of Electricity and Telegraphs, National Railways of Mexico. November 13. Attendance 35.

Minnesota

Dinner Dance. November 20. Attendance 82.

Automatic Network for A-c. Systems, by H. Richter, Central Station Engr., Westinghouse Electric & Mfg. Co. December 4. Attendance 46.

Nebraska

Mercury Arc Rectifiers in Electrical Railway Traction Service, by George Swallow, Sales Engr., American Brown-Boveri Co. Illustrated with slides. Some discussion followed the talk, centering on the interference caused by rectifier operation to telephone circuits. O. K. Marti, Chief Engr., American Brown-Boveri Co., explained what had been done in Dubuque for the reduction of interference. November 26. Attendance 26.

New York

Crystals and Waves, by Dr. Karl K. Darrow, Bell Telephone Laboratories, Inc. Illustrated. November 13. Attendance 600.

Niagara Frontier

On invitation of the Engineering Society of Buffalo, a demonstration of electric arc welding of the structural steel work of the new office and bank building of the Tonowanda Power Company at North Tonawanda, N. Y., was witnessed. The Western New York Section, American Welding Society and Electrical League of the Niagara Frontier also cooperated. August 16.

Transient Phenomena, by K. B. McEachron, Research Engr., General Electric Co. Illustrated with slides. A dinner preceded the meeting. September 28. Attendance 125.

Developments in Photo-Radio, by Capt. R. H. Ranger, Radio Engr., Radio Corp. of America. Joint with Buffalo-Niagara Section, Institute of Radio Engineers. October 12. Attendance 110.

Televox, the Electrical Man, by J. L. McCoy, Westinghouse Electric & Mfg. Co. The meeting was in cooperation with the Engineering Society of Buffalo. October 16. Attendance 400.

Trends in Electric Drives in Steel Mills, by A. F. Kenyon, Westinghouse Elec. & Mfg. Co.;

Reversing-Mill Drives, by L. A. Umansky, General Electric Co., and

The Manufacture of Steel, by G. A. Richardson, Bethlehem Steel Co. In the afternoon an inspection trip was made to the Lackawanna Plant, followed by a dinner at the Hotel Statler. The Societies invited to participate in the meeting were: The Engineering Society of Buffalo and the Affiliated Societies; Niagara Section, the Institute of Radio Engineers; Toronto Section, A. I. E. E., and Niagara, Hamilton and Toronto Branches, Engineering Institute of Canada. October 25. Attendance 150.

Pittsburgh

Transient Phenomena, by K. B. McEachron, General Electric Co. Comedy movies were shown preceding the talk. Joint meeting with Electrical Section, Engineers Society of Western Pennsylvania. November 13. Attendance 128.

Pittsfield

The Romance of Power, by C. M. Ripley, General Electric Co. Illustrated with slides. The speaker was entertained at dinner previous to the meeting. November 6. Attendance 650.

Modern Developments in Physics, by Dr. Saul Dushman, General Electric Research Laboratory. The speaker was entertained at dinner previous to the meeting. November 20. Attendance 110.

Portland

Industrial Importance of American Society for Testing Materials, by C. L. Warwick, Secretary-Treasurer, American Society for Testing Materials. Joint meeting of the various engineering societies under the auspices of the Oregon Technical Society. October 17. Attendance 75.

Power Factor from a Central-Station Viewpoint, by Wm. S. Hill, Gen. Supt., Grays Harbor Railway and Light Co. November 27. Attendance 65.

Providence

Electrical Eyes, by R. A. Deller, Bell Telephone Laboratories, Inc. Joint with A. S. M. E., preceded by a dinner for the speaker. December 4. Attendance 120.

Rochester

Short Waves, by C. A. Priest, Engr., Radio Dept., General Electric Co. Joint meeting with Rochester Engineering Society and Rochester Section, Institute of Radio Engrs., preceded by a dinner. December 7. Attendance 66.

St. Louis

Electric Refrigeration, by W. M. Timmerman, Committee Engr., Electrical Refrigeration Dept., General Electric Co. Motion pictures. November 21. Attendance 82.

Seattle

Economics of Interconnection, by O. L. LeFever, General Supt., Northwestern Electric Co., and

The Mechanical Man, by W. B. Wilfley, Engr., Westinghouse Electric & Mfg. Co. Televox demonstration. The speaker was entertained at dinner. November 20. Attendance 173.

Sharon

Lightning Problems and Lightning Research, by J. H. Cox, Transmission Engr., Westinghouse Electric & Mfg. Co. Two motion pictures,—one showing, in cartoon form, telephone circuits, and the other entitled "The Little Big Fellow." November 13. Attendance 131.

Springfield

Small-Motor Design and Characteristics, by R. Ehrenfeld, Westinghouse Electric & Mfg. Co. Illustrated. September 17. Attendance 72.

Test Apparatus and Methods of Checking the Characteristics of Radio Sets, by M. G. Sateren, Westinghouse Electric & Mfg. Co. Illustrated with slides. October 22. Attendance 48.

Lightning Protection for Transmission Lines and Apparatus, by K. B. McEachron, General Electric Co. November 26. Attendance 48.

Syracuse

Electrical Transmission of Personality, by L. S. O'Roark, Bell Telephone Laboratories. November 19. Attendance 157.

Welding Steel Bridges and Buildings, by Prof. F. P. McKibben. Illustrated. Joint with A. S. C. E. and Syracuse Architects Club, in conjunction with the Technology Club. December 3. Attendance 225.

Toledo

Electric Welding of Steel Buildings and Bridges, by F. P. McKibben, Consulting Engr. Joint with A. S. M. E. and A. E. E. November 12. Attendance 80.

Toronto

Electric Welding as Applied to Machine Fabrication and Structural Steel, A. M. Candy, Westinghouse Electric & Mfg. Co. November 9. Attendance 96.

Electrical Engineering in Mexico, by W. J. Gibson, Eastern Power Devices. November 24. Attendance 57.

Urbana

Problems, Methods and Laboratories of High-Voltage Research, by J. T. Tykociner, Research Assistant Professor of Electrical Engineering, University of Illinois. November 20. Attendance 65.

Utah

The Function of Research in Human Progress, by Dr. Adams S. Bennion, Personnel Director, Utah Power & Light Co. October 15. Attendance 50.

Salt Lake City as a Radio Broadcasting Center, by E. J. Glade, Mgr., K. S. L., and

Introducing the New K. S. L. Transmitter, by J. N. Cope, Radio Technician of K. S. L. November 19. Attendance 75.

Washington

The New Spirit in Lighting, by A. L. Powell, Mgr., Engg. Dept., Edison Lamp Works, General Electric Co. Illustrated by slides and demonstrated. A dinner in honor of the speaker was served before the meeting. November 13. Attendance 155.

A. I. E. E. Student Activities

ELECTRICAL SHOW AT MONTANA STATE COLLEGE

The Montana State College Branch held an electrical show on Saturday night, December 8, 1928, for the purposes of demonstrating to the public the wide and varied field of electricity and giving the students more practical training in the laboratory. The attendance was about 275.

A program including the following twenty-six exhibits was supplied by the juniors and seniors in electrical engineering: speaking arc lamp, artificial lightning, eddy current cooking demonstration, tin can motor, electrical spot welding, electrical forge—(2), electrical chick hatching, electrical fish pond, electrical flowers, electrical smoke precipitation, reversing motor, oscillograph demonstration, street car motor and control, series arc lamps and generators, automatic telephone, radio controlled car, artificial telephone line demonstration, electrical meter operation, high frequency currents, X-ray demonstration, magneto voltage test, lifting magnet, mercury arc rectifier, winking lights, radio set.

CONVENTION OF STUDENT BRANCHES IN OHIO

A very interesting and successful Student Convention was held at Ohio State University, Columbus, Ohio, December 7 and 8, 1928. Five of the six Branches in the state participated, the four visiting Branches being represented by delegations ranging from nine to twenty-eight students.

Friday Afternoon

Following a luncheon, an inspection trip was conducted through the Engineering Laboratories, Radio Station WEAO, Experiment Station, University Power Plant, Stadium, Industrial Engineering Shops, and the Chemistry Department.

Friday Evening

At the dinner meeting held on Friday evening, the principal speaker was D. T. Fisher of the Jeffrey Manufacturing Company, whose address on the subject "Patents and Their Relation to Engineering" was greatly enjoyed by the 110 persons who were present. It was followed by a lively and beneficial discussion.

A résumé of A. I. E. E. Student Activities was given by Professor F. C. Caldwell, Counselor, Ohio State University Branch, and Chairman of the Committee on Student Activities of the Middle Eastern District. Professor H. B. Dates, Counselor of Case School of Applied Science Branch, gave a brief talk upon his experiences in Student Branch work.

Saturday Morning

Résumé of Branch Activities:

W. A. Thomas, Chairman, Case School of Applied Science Branch.

C. C. Kelch, Chairman, Ohio University Branch.

R. F. Rice, Chairman, Ohio Northern University Branch.

G. W. Trout, Secretary, Ohio State University Branch.

C. D. Tinley, Chairman, Municipal University of Akron Branch.

The following papers were presented by students:

Arc Welding, W. C. Sanow, Case School of Applied Science.

Student Publications, C. C. Keller, Ohio State University.

Railway Electrification, W. C. Hensel, Ohio Northern University.

Development of a New High Temperature Solder, E. M. Stanbery, Ohio State University.

The Verigraph, Harmon Shively, Municipal University of Akron.

The above talks were followed by discussions by the Counselors. The attendance at this session was about 160.

A second inspection trip was conducted on Saturday afternoon.

Plans for the Convention were made under the supervision of a general committee, of which Robert H. Spry, Chairman of the Ohio State University Branch, was Chairman.

BRANCH MEETINGS

Municipal University of Akron

Development of Radio, by T. S. Starr, Student, and

The Verigraph, by H. G Shively, Student. Prof. J. T. Walther, Counselor, and P. C. Smith, Instructor, gave short talks. Prof. Walther suggested that the best paper of the year be chosen by the members themselves and the author be given some honorary mention. November 8. Attendance 16.

Motion picture, "Conowingo." Seven members expressed their intention to attend the Student Convention at Ohio State University. December 5. Attendance 15.

Alabama Polytechnic Institute

Business meeting. Discussion of plans for an inspection trip and a smoker. November 8. Attendance 44.

Accident Prevention, by C. D. Bradley, Student, and

Operation of the Movietone, by W. T. Edwards, Student. J. H. Shirley, J. D. Neeley, T. S. Winters and R. A. Sansing, Students, gave impromptu talks on summer experiences. November 15. Attendance 45.

Smoker. The program consisted of impromptu talks. November 22. Attendance 60.

Electrical Refrigeration, by F. Cardwell, Student. Final arrangements made for the inspection trip to be held December 8. December 6. Attendance 41.

University of Arkansas

Motion picture "Production of Electrical Cable," followed by a business session. December 6. Attendance 15.

Brooklyn Polytechnic Institute

Relays, by J. McLoughlin, Relay Dept., Westinghouse Electric & Mfg. Co. November 16. Attendance 31.

California Institute of Technology

Cross-Line Induction Motors, by Earl Mendenhall, Secretary and Chief Elec. Engr., Sterling Electric Motor Co. Prof. R. W. Sorensen, Counselor, made an announcement concerning student papers to be given at a meeting of the Los Angeles Section. Refreshments were served. November 21. Attendance 20.

University of California

The Economic Aspect of Stocks and Bonds, by G. A. Anderson, Senior, and

New Long Distance Communicating Systems, by W. C. Harcus, Pacific Tel. & Tel. Co. Discussion of plans for inspection trips. Prof. T. C. McFarland, Counselor, reported that many students had volunteered talks on varied subjects in returning the questionnaires distributed at the previous meeting. November 7. Attendance 40.

New Developments in Electrical Engineering, by J. F. Spease, General Electric Co. A. G. Jones, Secretary, San Francisco Section, gave a brief talk. November 21. Attendance 33.

Carnegie Institute of Technology

Transmission of Pictures by Radio, by O. V. Mitchell, Student, and

Underground Networks, by J. R. Britton, Student. Plans for Electrical Smoker discussed. Committees appointed. Short social meeting with the usual eats and smokes. November 7. Attendance 42.

Research, by Thomas Spooner, Research Engr., Westinghouse Electric & Mfg. Co. Moving picture—"Electrical Measurements." Discussion concerning Electrical Smoker to be held December 12. Short social meeting with usual eats and smokes. December 5. Attendance 49.

Clemson Agricultural College

Insulating Materials, by F. W. Lachicotte, Student;

Electric Welding, by H. C. Causey, Student;

Television, by G. W. Sackman, Student, and

Current Events, by J. F. Williams, Student. Prof. S. R. Rhodes, Counselor, gave a brief talk on television equipment. November 22. Attendance 34.

Colorado State College

Television, by Prof. H. G. Jordan, Counselor. Business meeting. December 10. Attendance 12.

University of Colorado

Lightning, by Prof. Frank Eastom, Dept. of Elec. Engg. November 21. Attendance 50.

Cooper Union

High-Tension Underground Cables, by F. M. Farmer, Chief Engr., Electrical Testing Laboratories. Illustrated with slides. December 5. Attendance 90.

Denver University

Steam Turbines, by H. A. Hake, General Electric Co. Several slides were shown. November 23. Attendance 34.

University of Detroit

Speed Control of Direct Current Motors, by J. J. Bialko, Student. Movies—"King of the Rails." Comments on movies and a discussion of the new type of Ford Electric Railway Locomotive, by H. O. Warner, Counselor. November 15. Attendance 26.

Drexel Institute

Business session followed by a talk by E. O. Eichna, Student, on Dr. Michael I. Pupin. November 2. Attendance 16.

Duke University

Regional Meeting of the A. I. E. E. at Atlanta, by Prof. W. J. Seeley, Counselor, and

Origin, Purpose and Value of the A. I. E. E., by Prof. S. R. Schealer, Dept. of Elec. Engg. Motion passed that the program committee assign definite dates for each member of Branch to give a paper. November 16. Attendance 16.

Georgia School of Technology

Business meeting. Discussion of plans for the year. Members of following committees appointed: Executive, Publicity, By-Laws, Inspection Trips, Obtaining Speakers, Meetings, and Smoker. November 13. Attendance 14.

Four reels of motion pictures on radio and construction of transformers. November 16. Attendance 60.

Business Meeting. Reports of various committees regarding the smoker, inspection trips, etc. December 4. Attendance 15.

University of Iowa

Business meeting. Election of officers. September 19. Attendance 31.

The Duties of a Safety Engineer, by Earl Flannagan, Student. September 26. Attendance 34.

Electric Arc Welding, by E. R. Arvidson, Student, and

Street Lighting, by P. G. Arvidson, Student. October 3. Attendance 30.

Duties of the Engineer at the Power Plant, by J. Crookham, Student. October 10. Attendance 24.

Are Electric Railways Coming Back?, by J. W. Campain, Student, and

Electrical Energy and National Defense, by E. M. Ellingson, Student. October 17. Attendance 33.

Kansas State College

Summer Experiences with the Central Station Institute, Chicago, by Mr. Ellifrit, Student. Prof. R. G. Kloeffler, Counselor, made an announcement in regard to the two sections of the Branch and the A. I. E. E. regional meeting. Lester Means, General Electric Co., gave a talk on the opportunities offered by the General Electric Company to college graduates. October 18. Attendance 76.

Storage Batteries, by Mr. Herren, Student, and

Jobs and Personalities, by Prof. R. G. Kloeffler, Counselor. Film—"Back at Westinghouse with Kansas State Boys," November 1. Attendance 75.

Summer Experiences with the Central Station Institute of Chicago, by E. V. Ellifrit, Student. Lester Means, General Electric Co., gave a brief talk regarding the General Electric Company. October 18. (Evening).

Television, by A. W. Vance, Student. Moving pictures—"Back at Westinghouse with the Kansas State Boys." November 1. (Evening).

University of Kansas

Large Interconnecting Systems, by R. C. Bergvall, General Engr., Westinghouse Electric & Mfg. Co., and

The Engineer and Promotional Work, by J. L. Harrington, Consulting Engr. Joint meeting with Kansas City Sections of A. I. E. E. and A. S. M. E. November 13. Attendance 150.

University of Kentucky

Use of Synchronous Converters for Power Factor Correction, by a Student. Talk by a representative of the American Telephone and Telegraph Co. November 21. Attendance 42.

Synchronous Motor for Power Factor Correction, by a Student;

Mercy Arc Rectifiers Substations, by a Student, and

Electricity—Pathway to Prosperity, by a Student. December 5. Attendance 40.

Lafayette College

Motion picture—"Driving the Longest R. R. Tunnel in the Western Hemisphere." November 3. Attendance 21.

Lewis Institute

Motion picture—"Separating Facts from Opinion." Chairman Gaimari gave a brief account of the lecture "Making Light Audible and Sound Visible," by John B. Taylor, which he had heard on the 19th. Joint meeting with W. S. E. Branch. November 20. Attendance 119.

Business Meeting. It was decided to urge students to present papers of technical nature at regular Branch meetings and prepare papers for the regional meeting of District No. 5. November 26. Attendance 11.

Louisiana State University

Experiences about the Plant and the High Voltage Lines That Are Now Taking the Place of the Small Power Houses, by Mr. Davis, Chief Engr., Baton Rouge Electric Co. November 30. Attendance 26.

The Bell System's Organization and the Opportunities Offered, by Mr. Horne, Southern Bell Telephone Co. December 7. Attendance 17.

University of Louisville

Business session, followed by talk by Chairman Samuel Evans on his trip to Atlanta and Washington and the papers delivered at the Regional Meeting in Atlanta. November 22. Attendance 10.

University of Maine

15,000-Kw. Frequency Converter, and *Steel Mill Drive*, by E. G. Sylvester, Student, and

Summer's Work with Westinghouse Electric & Manufacturing Company, by H. E. Ellis, Student. November 22. Attendance 37.

Massachusetts Institute of Technology

O. W. Eshbach, Personnel Dept., A. T. & T. Co., represented the communications field in the series of talks upon "The Opportunities for Electrical Graduates in the Electrical Industries." Two reels of film on the telephone industry. Free supper preceded the program. November 9. Attendance 282.

N. H. Daniels, Stone & Webster, Inc., represented the construction field in the third meeting devoted to the subject "The Opportunities for Electrical Graduates in the Electrical Industries." Three reels of film on large electrical construction projects. A free supper preceded the program. November 23. Attendance 288.

School of Engineering of Milwaukee

Safety in Night Driving, by E. J. Lehnen, Secretary and Chief Engr., Day-Nite Corp. Membership and Auditing Committees appointed. October 12. Attendance 230.

University of Missouri

The General Electric Student Training Course, by C. M. Wallis, Instructor, and

The Maximum Limits of Power Transmission, by J. H. Cooper, Student. The Branch decided to select, for presentation at the Regional Meeting at Dallas, two papers from a number to be submitted by various students. October 29. Attendance 33.

Montana State College

Metallic Arc Welding Electrodes, by J. B. Green, from A. I. E. E. JOURNAL, June, 1928,—presented by R. H. Crumley;

Welding, Manufacture, and Design of Large Electrical Machines, by A. P. Wood, from A. I. E. E. JOURNAL, March, 1929,—presented by Murray Davidson, and

Packard Aircraft Engine Ignition, from *Chicago Engineering Review*, October, 1928. November 15. Attendance 72.

High-Speed Circuit Breakers, by T. W. McNairy, from A. I. E. E. JOURNAL, October, 1928,—presented by Glenn Montgomery, and

Great Northern Railway Electrification in the Cascades, by E. L. Moreland, from A. I. E. E. JOURNAL, November, 1928,—presented by V. Morgan. November 22. Attendance 69.

University of Nevada

Three reels of motion pictures, two on electrical equipment in the Cuban sugar refineries and one showing air views of Rena and Lake Tahoe. Plans for Homecoming Day, October 27, discussed. Coffee and doughnuts. September 26. Attendance 25.

Newark College of Engineering

Transatlantic Telephony, by G. R. Ottinger, New Jersey Bell Telephone Co. Illustrated. Business session. December 3.

University of New Hampshire

Transient Phenomena, by J. W. Langford, student, and

Lightning Protection, by E. B. Moore, student. November 3. Attendance 14.

Rates and Load Building, by Robert Adams, Student;

Maintenance of Gasoline-Electric Vehicles, by Watson Adams, Student, and

The Senior Inspection Trip, by Robert Learned, Student. November 17. Attendance 26.

Theatre Lighting Effects, by J. F. Arren, Student;

What Can Television Do? by B. O. Atwood, Student, and

Direct Current Generators for Very High Voltage, by R. G. Ballard, Student. November 24. Attendance 34.

Philadelphia Electric Company, by Mr. Stevens, alumnus. Mr. Smith, alumnus, gave a talk on various services given by the Western Union Telegraph Company. December 1. Attendance 34.

Moving picture—"The Single Ridge," December 8. Attendance 34.

College of the City of New York

Inspection trip to the Audubon Exchange of the New York Telephone Co. November 21. Attendance 11.

Business meeting. November 22. Attendance 15.

Inspection trip to the Edgecombe Exchange of the New York Telephone Co. December 5. Attendance 8.

Diesel-Engines, by T. D. Slingman, Fairbanks-Morse & Co. Motion pictures—"Making Mazda Lamps" and "Big Deeds." December 6. Attendance 44.

New York University

Inspection trip to the Bell Telephone Laboratories, Inc., Experimental Radio Broadcasting Station 3XN at Whippany, New Jersey. November 15. Attendance 24.

The Embryo Engineer Seeks Entrance into the Engineering Profession, by Maxwell Bricks, alumnus, General Electric Co., and

Rectifiers as Used in Broadcast Receiving Sets, by A. B. Cantor, Student. Business session. November 19. Attendance 20.

North Carolina State College

Pole Treatment, by Geo. Roewe, Distribution Engr., Carolina Power and Light Co. December 4. Attendance 37.

University of North Carolina

Television, by Prof. T. B. Smiley, and

Parlor Engineering, by Prof. A. C. Howell. November 22. Attendance 31.

University of North Dakota

Salaries of Engineers after Graduation, by J. K. Walsh, Student. November 15. Attendance 19.

Placing the College Graduate in Industry, by Mr. Aaker, Student. Three reels motion pictures—"The Single Ridge." December 6. Attendance 21.

Ohio Northern University

Railroad Electrification, by W. G. Hensel, Student, and

The Engineer as the Employer Sees Him, by P. D. Luikart, Student. Plans made for attending the Student Convention at Ohio State University on December 7 and 8. November 22. Attendance 28.

The Construction of High-Tension Transmission Lines, by L. W. Hill, Student. December 6. Attendance 26.

Ohio State University

Research in Engineering, by Thomas Spooner, Research Engr., Westinghouse Electric & Mfg. Co., Illustrated. A dinner preceded the meeting. November 11. Attendance 55.

Ohio University

Inspection trip through the new automatic-equipped telephone building of the Athens Home Telephone Co. The following officers elected: Chairman, Clarke Kenney; Vice-Chairman, Melvin Ziegler; Secretary, Harold W. Giesecke. November 14. Attendance 13.

Oklahoma A. & M. College

Three reels—"The Benefactor." Charman E. L. Weathers discussed the programs planned for this year and the benefits derived from Branch membership. November 15. Attendance 31.

Oregon State College

Three reels—"The King of the Rails." November 19. Attendance 64.

University of Pittsburgh

F. R. Garman, Bell Telephone Company of Pa., demonstrated several different types of loud-speakers using an electric phonograph pick-up with a power amplifier. Two reels of films—"The Big Little Fellow" and "Voices Across the Sea." Light refreshments. October 26. Attendance 53.

The Importance of Cooperative Work in an Engineer's Training, by R. J. Anthony, Student, and

Some Aspects of the Conowingo Power Project, by R. H. Capek, Student, November 2. Attendance 72.

Wheels, by H. K. Fried, Student, and

Engineering Principles in Art, by W. T. Millis, Student. November 9. Attendance 75.

New York Subways, by L. E. Ensley, Consulting Engr. Joint meeting with A. S. M. E. Branch. November 16.

Princeton University

Carboloy and High-Speed Cutting Tests in Relation to Electrical Engineering, by I. H. Dixon, Student, and

Transatlantic Radio, by A. J. Stobbe, Student. November 26. Attendance 13.

Automatic Train Control, by Mr. Murray, Student, and

Voltage Surges in Transmission Lines, by W. V. Eakins, Student. December 10. Attendance 13.

Rensselaer Polytechnic Institute

Three reels—"Manufacture and Use of Weston Meters." October 18. Attendance 80.

Talks on summer experiences by the following students: A. C. Scribner, New York Edison Co.; J. L. Leach, New York Edison Co.; W. S. W. Edgar, Dayton (Ohio) Power & Light Co.; G. A. Smith, Westinghouse Electric and Mfg. Co.; George Brace, N. Y. C. R. R. Signal System; P. H. Grogan, Rome Wire Co.; Edward Hughes, Alabama Power Co.; N. V. Cargill, Rochester Gas and Electric Co. Frank Cubello and Patrick H. Grogan appointed to Executive Committee. November 13. Attendance 50.

Rhode Island State College

Early Developments in Electrical Engineering, by Prof. A. E. Watson, Head of Electric Engg. Dept. of Brown University. November 21. Attendance 43.

Modern Illumination, by C. M. Snyder, Illuminating Engr., National Lamp Works, General Electric Co. November 28. Attendance 30.

Conowingo Power Development, by R. V. P. Cahill, Student. December 5. Attendance 40.

Rose Polytechnic Institute

Talks on the Conference on Student Activities of Great Lakes District held at Chicago on December 3, by Prof. C. C. Knipmeyer, Counselor, Chairman Dowen, and Mr. Moench and Mr. Bailey of the Program Committee. December 7. Attendance 34.

Rutgers University

A talk by the faculty upon "The Advantages to the Student of Enrolment in the A. I. E. E." Discussion of future inspection trips. November 19. Attendance 21.

University of South Carolina

Aircraft Radio Beacons, by Frank Lucas, Student. Moving picture—"Electric Transformers." Plans made for an inspection trip to Saluda Dam. December 5. Attendance 16.

South Dakota State School of Mines

Construction of 200-Mile Natural Gas Line, by R. M. Burnham, Student, and

Installations of Central Battery Telephone System in 300-Room Hotel, by Lowell King, Student. November 9. Attendance 21.

University of South Dakota

Selection and Use of Motors, by Chairman C. R. Cantonwine. December 3. Attendance 11.

University of Southern California

Construction, Operation and Possibilities of All-Metal Dirigibles, by G. C. Slate, Slate Aircraft Corp. November 1. Attendance 28.

The Use of the Electric Arc in Welding, by W. B. Fish, Westinghouse Electric & Mfg. Co. Joint meeting with A. S. C. E. Chapter. November 22. Attendance 59.

Stanford University

Electric Ships, by W. G. Hoover, Student;

The High-Voltage Coolidge Tube, by D. H. Ring, Student, and

Lightning, by W. B. Duncan, Instructor in Elec. Engg. The opinion of the members was asked regarding the desirability of student talks and it was strongly recommended that they be continued. November 8. Attendance 20.

Swarthmore College

Railway Electrification, by Dr. L. Fussell, Counselor. D. B. Spangler elected Chairman of the Branch. November 8. Attendance 20.

Syracuse University

Difficulties Due to Low Pressure Heads in Power Generation, by Mr. Barrows, Student, and

Mercury-Arc Power Rectifiers, by Mr. Behm, Student. October 23. Attendance 22.

The Surge Recorder Klydonograph, by Mr. Belayeff, Student, and

Television, by Mr. Bryant, Student. October 30. Attendance 22.

Photo-Electricity, by Mr. Casavant, Student, and

The Use of Hydrogen As a Cooling Medium, by Mr. Deyoe, Student. November 6. Attendance 21.

The Cathode-Ray Oscillograph, by Mr. Goldstein, Student, and

The Handling of a Telephone Call by Machine Switching, by Mr. Greenman, Student. November 13. Attendance 22.

The Manufacture of Hydrogen, by Mr. Martin, Student, and

The Different Methods of Television, by Mr. Hough, Student. November 20. Attendance 21.

University of Tennessee

Talk by President Fleming on value and purpose of the A. I. E. E. Program and Advertising Committees appointed. October 25. Attendance 30.

Lightning Experimental Station at Chilohwee, Tenn., by Mr. Sparks, Westinghouse Electric & Mfg. Co. November 8. Attendance 86.

Motion pictures—"Driving the Longest Railroad Tunnel in the Western Hemisphere" and "Power Transformers." November 22. Attendance 69.

Texas A. & M. College

Underground Power Distribution System of Dallas, by T. A. Pilkey, Student. Two motion pictures—"Ties of Steel," and "X-Rays." November 16. Attendance 90.

University of Texas

Airways and Airport Lighting, by C. R. Granberry, Instructor, E. E. Dept. October 25. Attendance 14.

Film—"Manufacture of Insulated Wire." November 8. Attendance 11.

Experiences with the Southwestern Bell Telephone Company during the Past Summer, by Archie Straiton, Senior. November 22. Attendance 11.

University of Utah

Chairman Ned Chapman gave report on the Pacific Coast Convention held in Spokane. Program Committee appointed. November 8. Attendance 18.

University of Vermont

Business session followed by talks on "Arc Welding" by A. A. Piche, Student, and "Picture Transmission and Amateur Radio Television," by F. L. Sulloway, Student. October 27. Attendance 18.

Automatic and Semi-Automatic Machines, by R. Flanders, Jones and Lamson Machine Co. Slides. Joint meeting with A. S. M. E. November 13. Attendance 28.

Talking Movies, by R. F. Bigwood, Student, and

Transformers, by Prof. L. P. Dickinson, Counselor. Film. November 27. Attendance 15.

Virginia Polytechnic Institute

Reports on Regional Meeting at Atlanta, Ga., October 29-31, by J. L. Rothgeb, Chairman and Prof. Claudius Lee, Counselor. It was decided to make the meetings more helpful by having papers presented by students, mainly. Appointment of Program Committee. A committee to prepare program for the next meeting was appointed. November 9. Attendance 20.

Washington University

Electrical Engineering in General, by J. L. Hamilton, Chief Engr., Century Electric Co. J. Spies, senior, elected representative to the Engineers' Council. November 20. Attendance 29.

University of Washington

Four Element Tube, by Frank Giovanini, graduate student. November 2. Attendance 20.

Sidelights on Heaviside, by G. S. Smith, Ass't Prof. of Elec. Engg. November 9. Attendance 24.

The Stone Way Bridge, by Norman Haner, Student. November 16. Attendance 27.

West Virginia University

The following papers were presented by Students: *High Voltage Insulators*, by L. F. Oneacre; *Catawaba River Dam and Power Plant*, by W. C. Warman; *Protective Grounds*, by C. B. Seibert; *A Mammoth Railroad Fill*, by A. F. Fervier; *Adjustment of 258-Ton Rotors*, by R. N. Kirchner; *Lodgepole Pines for Line Poles*, by C. E. Moyers; and *Carboloy*, by B. L. Williams. Critics were C. A. Bowers, Jr., M. C. Clark, and T. D. Nixon. November 12. Attendance 28.

The following papers were presented by students: *Carboloy*, by R. I. Boone; *Progress of 220 K. V. Developments*, by W. H. Unger; *Constant Current Transformers*, by G. W. Pride; *Hydraulic Testing Devices*, by W. H. Sutton; *Earth's Electrical Charge*, by O. R. Allen; *New Jobs for X-Rays*, by B. L. Williams; and *Watching the Death Whisper Kill*, by S. N. Gidding. Critics were G. W. Barnes, G. I. Burner, L. F. Oneacre, and J. E. Winter. November 19. Attendance 30.

The following papers were presented by Students; *The Electrolytic Zinc Plant of the Sullivan Mining Company*, by W. C. Warman; *Improved Radio Beacon for Airplanes*, by C. B. Seibert; *Electric Detonators*, by P. E. Davis; and *Electricity and the Student*, by J. S. Merritt. December 3. Attendance 32.

The following papers were presented by Students; *The Increased Consumption of Electricity in Rural Districts*, by T. R. Cooper; *Why Rivets and Bolts in Transformer Cores Should be Insulated*, by T. D. Nixon; *Hydro-Electric Development along the Ohio River*, by L. F. Oneacre; *World's Power Resources*, by M. S. Diaz; *Use of Steel in Switchboard Design*, by W. H. Sutton and W. S. Bosley; *Field Balancing of Rotors*, by C. C. Coulter; *Oxy-acetylene Welding*, by F. D. McGinnis. The critics were Ivan Dannoy, G. I. Burner, W. S. McDaniels, and N. S. Gidding. December 10. Attendance 25.

Worcester Polytechnic Institute

Televox, by R. J. Wensley, Westinghouse Electric & Mfg. Co. Demonstration. Joint meeting with Worcester Section. December 10. Attendance 400.

University of Wyoming

A 3000-Volt Locomotive for South American Service, by Harold Anderson, Student. Illustrated lecture.

Train Radio, by Stephen Anderson, Student. Illustrated lecture. Adoption of By-laws. Election of officers. November 13. Attendance 10.

Motor Controllers, by Mr. Joslin, Student. Appointment of Executive, Membership, Publicity, Program and Engineers Open House Committees. General get-together meeting with refreshments followed the program. November 25. Attendance 18.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES, NOV. 1-30, 1228.

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Aerial Photography; a comprehensive survey of its practice and development.

By Clarence Winchester and F. L. Wills. Boston, American Photographic Publishing Co., 1928. 236 pp., illus., plates, 10 x 8 in., cloth. $10.00.

Contains a wealth of practical information upon aerial photography which will be decidedly useful to all those interested. The material and apparatus now available is described in detail. the authors giving the results of their wide experience. In the final section the applications of aerial photography to surveying, mapping archaeology and other sciences are indicated.

Atlas der Letzten Linien der Wichtigsten Elemente.

By Fritz Löwe. Dresden u. Leipzig, Theodor Steinkopff, 1928. 44 pp., plates, tables, 9 x 6 in., cloth. 12.-r. m.

This atlas is especially prepared to meet the practical needs of those engaged in spectrum analysis. It gives the lines that are still apparent when elements are present in only small amounts in mixtures, alloys, solutions, etc., and covers only that part of each spectrum which is of interest to the analyst. Four spectra for concentrations of 1%, 0.1%, 0.01%, and 0.001% are given for each element. The illustrations are very clear, and the price is moderate.

Bildungswerte der Technik.

By Hermann Weinreich. Berlin, V. D. I. Verlag, 1928. 151 pp., illus., 8 x 6 in., cloth. 7.-r. m.

An able argument for the educational value of technical training. The author discusses current misconceptions concerning the relative importance of scientific and humanistic studies, calls attention to the contributions of technology to civilization and culture, and discusses its place in general education.

Electric Lines and Nets.

By A. E. Kennelly. 2d edition. N. Y., McGraw-Hill Book Co., 1928. 426 pp., illus., diagrs., tables, 9 x 6 in., cloth. $5.00.

This is a thorough revision of the author's "Artificial Electric Lines," much of the earlier material having been abridged and condensed, new material added, and the work enlarged to include real lines.

L'Electrochemie et L'Electrometallurgie.

By Albert Levasseur. 3rd edition. Paris, Dunod, 1928. 361 pp., diagrs., 10 x 7 in., paper. 73 fr.

Discusses the theory of electrolysis and of the electric furnace, together with a number of the important industrial applications of them. The work gives a clear outline of principles and a considerable amount of practical information within moderate compass, and is designed for use both by students and engineers. This new edition is considerably enlarged, especially with respect to the electric furnace.

Empfindliche Galvanometer fur Gleich-und Wechselstrom.

By Otto Werner. Ber. u. Lpz., Walter de Gruyter & Co., 1928. 208 pp., illus., 9 x 6 in., paper. 13.-r. m.

A treatise on the proper construction of the various types of galvanometers, with a discussion of the sensitiveness attainable with each type. Various accessories are treated, such as reading devices, vibrationless suspensions, etc. The work will interest makers and users.

The Engineer; His Work and His Education.

By Robert Lemuel Sackett. Bost. & N. Y., Ginn & Co.; 1928. 196 pp., illus., graphs, ports., 8 x 6 in., cloth. $1.40.

Written for the guidance of young men who are thinking of choosing engineering for their life work. The author discusses the aptitudes and abilities that the engineer should have, the financial rewards of the engineer, and the education given him at college. Various branches of engineering practice are analyzed, to assist in the selection of the most suitable one. An appendix contains brief biographies of a few famous engineers. Dean Sackett gives sound information which should be helpful to students in high schools and junior colleges.

Engineering Drawing.

By Harvey H. Jordan and Randolph P. Hoelscher. 2d edition, N. Y., John Wiley & Sons, 1928. 404 pp., illus., diagrs., 9 x 6 in., cloth. $3.00.

This textbook offers a sound course in engineering drawing, sufficiently detailed and comprehensive to meet all ordinary needs. The text is clear, the fundamental theories and concepts are carefully explained and the proper methods of executing drawings are shown. The book is based upon the courses given at the University of Illinois.

The Great Engineers.

By Ivor B. Hart. Lond., Methuen & Co., 1928. 136 pp., illus., 7 x 4 in., cloth. 3/6.

After a description of engineering in classical times, Dr. Hart surveys the beginnings of engineering science in medieval times, particularly as exemplified by the work of Leonardo da Vinci and Agricola. Attention is then directed to the great engineers of more recent times who gave to us control over power and materials by developing the steam and gas engines and producing iron and steel. For such a brief work, the book is an admirable survey of the development of engineering, told most attractively and clearly.

Heaviside's Electrical Circuit Theory.

By Louis Cohen. N. Y., McGraw-Hill Book Co., 1928. 169 pp., tables, 9 x 6 in., cloth. $2.50.

Although the importance of Heaviside's contributions to electrical theory is thoroughly recognized, the novel mathematical processes that he introduced and his failure to correlate and systematize his teachings have prevented the utilization of them by most engineers. Those to whom his writings have been a sealed book will welcome Dr. Cohen's work, which summarizes that part of Heaviside's mathematical analysis which bears upon the theory of the electric circuit.

The first chapter explains the principles of operational calculus. The expansion theorem is then elucidated. Succeeding chapters show the application of the theorem to transmission lines, electric filter circuits, and ocean cables.

History of the Sheffield Scientific School of Yale University, 1846-1922.

By Russell H. Chittenden. New Haven, Yale University Press, 1928. 2 v., illus., ports., 10 x 7 in., cloth. $10.00.

From 1872 until today Dr. Chittenden has been connected with the Sheffield Scientific School a student, professor, director and trustee. No one has had a better opportunity to know, at first hand, the course of its development, and these attractive volumes will long remain the definitive history of one of the earliest schools of engineering and science in America.

Impurities in Metals; Their Influence on Structure and Properties.

By Colin J. Smithells. N. Y., John Wiley & Sons, 1928. 157 pp., illus., diagrs., tables, 10 x 7 in., cloth. $5.00.

Dr. Smithells has collected the available information upon the effects of small amounts of elements upon the structure, mechanical and electrical properties, and corrosion of metals, and presents it here in a systematic manner. The effect of constituents present in concentrations below one per cent whether present intentionally or as impurities, is considered.

In view of the growing appreciation of the influence of minor constituents upon the properties of metals, this review of our knowledge will be welcome to metallurgists.

Industrial Organization and Management.

By William B. Cornell. N. Y., Ronald Press Co., 1928. 653 pp., illus., graphs, forms, 9 x 6 in., cloth. $5.00.

This textbook is intended to give engineers engaged in production and selling and students of business a knowledge of the fundamental principles of organization and management. The presentation is broad in scope and aims to reflect the most recent sound developments in this field.

Laws of Management Applied to Manufacturing.

By L. P. Alford. N. Y., Ronald Press Co., 1928. 266 pp., 9 x 6 in., cloth. $4.00.

The author of this work here attempts to formulate the fundamental principles of organization and management. Some fifty laws are given, which are believed to be basic, and each is discussed, with examples of its practical application. The book is based upon a paper presented before the American Society of Mechanical Engineers in 1926, here greatly amplified. It will be interesting to all executives and factory engineers.

Die Technik Elektrischer Messgerate, v. 2; Messverfahren.

By George Keinath. 3rd edition. Mün. u. Ber., R. Oldenbourg, 1928. 416 pp., illus., diagrs., 10 x 7 in., cloth. 24,50 r. m.

The second volume of Dr. Keinath's treatise on electrical measurements is devoted to methods of measurement. As in the first volume, attention is given especially to the methods commonly used in engineering practice and in the testing laboratory rather than to those of purely scientific interest.

In addition to the usual methods for measuring electrical quantities, such non-electric quantities as time, speed, and acceleration are considered. The sources of error and the accuracy of the various methods are given consideration. The book aims to be an exposition of the best current practice.

Vorlesungen Uber die Wissenschaftlichen Grundlagen der Elektrotechnik.

By Milan Vidmar. Berlin, Julius Springer, 1928. 451 pp., diagrs., 9 x 6 in., paper. 15.-r. m.

In presenting the theoretical principles of electrical engineering, Professor Vidmar has endeavored to avoid unrelated scientific facts and solutions of practical problems and has emphasized the physical and mathematical bases that underly the subject. The customary separation of alternating-current and continuous-current engineering is dropped, and the theory developed as a whole from electrophysics. The unusual treatment and the careful selection of the material give unusual interest to the book.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to **EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary: temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

PHYSICIST, with Ph. degree in physics for research work on radio and vacuum devices. Apply by letter stating age, nationality, training, experience and salary expected. Location, New York City. X-6526.

ELECTRICAL ENGINEER with electric locomotive and air-brake experience for assistant superintendent of maintenance on electric railroad, in Chile, South America. Apply by letter, stating age, married or single, education, experience, references and salary desired. X-6635.

DISTRIBUTION ENGINEER, as assistant in engineering department of public utility, electric. Must have at least three years' experience in engineering or operating department of public utility on distribution work. Underground experience desirable. Apply by letter giving age, experience, salary expected and enclose a small photograph. Location, Eastern New York. X-6136.

MEN AVAILABLE

GRADUATE, Cooper Union Night School '28 (B. S. in E. E.) desires position with engineering organization on technical staff; has had field experience with motors and control. Available two weeks' notice C-5329.

ELECTRICAL ENGINEER, 15 years' high- and low-tension experience, covering design, construction, installation, service and maintenance. Recently superintendent 3500 electrical hp. plant; resigned to enter United States, from Canada. Seeks connection with public utility or industrial concern, or would consider sales position, with some training. Middle west or California preferred. C-1989

ELECTRICAL ENGINEER, 36, married. technical university graduate; 15 years' broad experience in designing, projecting. estimating, construction and supervising on power plants, outdoor and indoor substations and industrial plants installation. Desires position with industrial concern, engineering organization or public utility. Available immediately. Prefers Eastern ocation. C-2011.

TECHNICAL GRADUATE, E E. and M E., 33; 14 years of general engineering experience, including three years of teaching. Would like to take up research, teaching or appraisal and evaluation work with public utility. Future prospects considered more important than initial salary. Best references. Available immediately. C-5213.

ELECTRICAL ENGINEER, with four years' public utility experience desires connection with management company or with the buying department of an investment house. Experience has been principally in general system development, economic, and cost analysis. Salary, $4000-$5000. Location, New York City. C-5302.

ELECTRICAL AND MECHANICAL ENGINEER, graduate, single. B. S. in M. E., 1927. One year Westinghouse Electrical Test Work. Desires position as junior engineer with an operating company. Available on short notice. Location, United States. C-5201.

ELECTRICAL EQUIPMENT INSPECTOR, 25, married; experience in factory acceptance tests on wire and cable, telegraph apparatus and power relay protective equipment. Available immediately. C-5297.

ELECTRICAL ENGINEER, 26, single, graduate B. S. degree in E. E; 1½ years' experience with electrical utility in all branches; 1½ years with telephone utility in construction and design. Desires location with utility or engineering organization. Location, immaterial. Available upon reasonable notice. C-5373.

ELECTRICAL ENGINEER, 28, single. Graduate Electrical Engineer. With General Electric Company 2½ years, including test and one year's research on automatic equipment; good experience in underground and overhead distribution. Desires connection with public utility or manufacturing concern. No preference as to location. C-3762.

GRADUATE ELECTRICAL ENGINEER, 29, married. One year G. E. test course; one year as instructor in electrical engineering; 5 years' diversified electric utility experience as switchboard operator, maintenance man, test engineer and assistant electrical engineer on substation construction. C-5186.

DESIGN ENGINEER, 37. Ten years' experience in development of d-c. motors and generators with reliable electrical manufacturer, capable of handling both the electrical and mechanical design of a wide variety of d-c. machines. At present employed; thirty days' notice to present employer required. Salary $5000. B-3152.

GRADUATE ELECTRICAL ENGINEER, of wide experience in power house and industrial plant design and construction, is open for a new engagement; has also some manufacturing, business and sales experience. Now employed. Location, East or Southeast. B-9222.

ENGINEER, 28, with 11 years' varied experience in the electrical industry, including railroad electrification, is desirous of making a permanent connection with corporation or architect with assurance of advancement for good work. Location preferred, New York City, though not imperative, no traveling. Salary, $3600 to start C-5367.

EDITOR, 33, married, technical school and college trained, 15 years' experience in publishing field covering practically every phase of editorial and advertising work. Thoroughly familiar with electrical, radio and general technical practise. Successful record of accomplishments. Desires responsible position with future. Location, New York City. C-829.

JUNIOR STUDENT in Electrical Engineering at Cooper Union Night School of Engineering, 23, industrious Experience: 3½ years in house wiring and in building and testing electrical motors, 3½ years drafting. Speaks English and German. Desires position of opportunity with a public utility or manufacturing concern in Electrical Engineering Department, Metropolitan area. Available on one week's notice. C-5401.

SALES ENGINEER, 31, married. B S. in E. E., three years sales engineer in charge of heat and sound insulation building materials for leading manufacturer; two years sales and service representative for prominent battery manufacturer; four years auto-electrical retail and service manager. New York or New Jersey preferred. C-75.

DESIGNING ENGINEER, electrical, for power plants and substations. Technical graduate, B. S. in E. E., with over 20 years' experience with large public utility and engineering corporations covering design, specifications, purchase of equipment, inspection, etc.; 10 years as Assistant Electrical Engineer. Good references. Moderate salary. C-3785.

ELECTRICAL COMMUNICATIONS TEACHER, 30, married; 3½ years' experience at Bell Telephone Laboratories. Ph D. in physics with special attention to electricity and acoustics. Thorough technical acquaintance with modern communication developments. Qualified to give undergraduate courses in electrical theory, measurements and communication; graduate courses in advanced communications. C-4919.

ELECTRICAL ENGINEERING GRADUATE, married. G. E. Test Course, 20 years' experience as supervisor and field engineer on construction of large power houses and substations. References furnished. Available on one month's notice. Location, United States. C-5394.

PURCHASER OF FOREIGN ELECTRICAL PROPERTIES. Can investigate, appraise, purchase, put on paying basis, and manage any property, group of properties, or number of groups. Have had broad experience in investigation,

appraisal and management in several countries. Now employed. C-4222.

RESEARCH PHYSICIST, 43, married. Last three years in responsible position, large phonograph concern. Former experience: professorship, executive positions, technical colleges, radio development, engineering. Research publications in positive and X-rays. Patented inventions, X-rays, radio, electrical instruments. Desires research, development position with opportunity for application of original ideas and chance for advancement. B-371.

GRADUATE ELECTRICAL ENGINEER with 10 years' experience as assistant to editor of *School Science and Mathematics*, assisting in editing of articles, writing, preparing book reviews. Assisted making dummy of magazine for printer to prepare page proofs of current issues. Familar with reading of page proof, preparatory to final setting for printing. C-4734.

TECHNICAL GRADUATE in E. E., 34, married, several years' experience in installation, construction and maintenance power plants and substations; also a year as assistant chief of plant; capable of producing results. Versed in foreign languages. Locations preferred, South or foreign; any considered. References present employer. C-2021.

ELECTRICAL ENGINEER AND DESIGNER, married. 16 years' experience, large power stations, steam and hydroelectric, high-tension indoor and outdoor substations, capable of taking responsible charge of drafting force. Licensed, New York State. Location, immaterial. B-5031.

ELECTRICAL ENGINEER, with many years' experience in this field, is about to receive Master of Business Administration degree at New York University, majoring in Corporation Finance and Investment Analysis, would like to connect with bank or investment house interested in South American financing. Speaks Spanish. B-7705.

MECHANICAL ENGINEER, member A. S. M. E., A. I. E E., 32, married, desires position as executive in charge of designing and manufacturing all types of machinery. Has wide experience in welded structures, heat treating methods, heavy and light machinery, tools efficiency programs, apprentice courses, etc. At present employed in similar position, available on one month's notice. C-5392.

ELECTRICAL CONSTRUCTION SUPERINTENDENT, 30, married. Graduate Electrical Engineer, Registered Professional Engineer, 10 years' experience, past six years on large power plants, substations, and ice plants for large public utility company. At present employed but will be available in 30 days, due to completion of construction program. C-5409.

ELECTRICAL MECHANICAL ENGINEER, American, married, executive ability with several years' experience ,design, development of signal and automatic-control systems for power and industrial plants, radio equipment, etc. Now employed but will consider suitable permanent opening with large company offering opportunity. Location preferred, East. B-2395.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held December 19, 1928, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

HENTZ, ROBERT A. Electrical Engineer, Philadelphia Elec. Co., Philadelphia, Pa.

KENDALL, BURTON W., Toll Systems Engr., Bell Telephone Laboratories, New York, N.Y.

LOWRY, HITER H., Systems Equipment Engr., Bell Telephone Laboratories, New York, N.Y.

MATTHIES, WILLIAM H., Local Systems Engr., Bell Telephone Laboratories, New York, N. Y.

POTTER, CHARLES P., Engr. in charge of Transformer and Large Motor Engg. Dept., Wagner Elec. Corp., St. Louis, Mo.

WOOLSTON, LOUIS F. B., Engineer, General Electric Co., St. Louis, Mo.

To Grade of Member

BAKER, PAUL W., Engr. in charge of Small Motor Division, Wagner Elec. Corp., St. Louis, Mo.

BOATRIGHT, HARVEY E., Supt. of Maintenance and Operation, Guanajuato Power & Elec. Co., Guanajuato, Gto., Mexico.

CAMPBELL, LOUIS O., Asst. to Office Engr., General Elec. Co., St. Louis, Mo.

CHIPPERFIELD, JOHN W., Chief Engr., Ferranti Elec. Ltd., Toronto, Ont., Canada.

COWLEY, JOHN R., City Electrical Engr., City Hall, Saskatoon, Sask., Canada.

COX, ISAAC E., Railway Service Engr., General Electric Co., St. Louis, Mo.

ELLIS, PAUL C., Asst. Supt., Engg. Research Lab., Kansas City Power & Light Co., Kansas City, Mo.

FOOTE, JAMES H., Electrical Engineer, Commonwealth Power Corp. of Michigan, Jackson, Michigan.

HAIG, JOHN MacDONALD, Transformer Supt., Ferranti Elec. Co., Toronto, Ont., Canada.

HILL, EDWARD P., Electrical Engineer, Metropolitan Vickers Electrical Co., Manchester, England.

KLIPPEL, FRANK H., Division Supt., Great Western Power Co., Sacramento, Calif.

PETERSON, WILLIAM S., Junior Electrical Engr., Los Angeles Bureau of Pr. & Lt., Los Angeles, Calif.

PLUMB, HENRY H. Associate Engineer, Bureau of Reclamation, Denver, Colorado

RUDISILL, WESLEY H., Vice Pres. and General Mgr., Chester Valley Elec. Co., Coatesville, Pa.

RUSSELL, FLOYD L., General Supt. of Construction, Public Service Production Co., Newark, N. J.

SMITH, ALLAN J., Vice Pres. aud Gen. Mgr., Texas Louisiana Pr. Co., Fort Worth, Texas.

WILLIAMSON CLAUDE A. Elec. Engr., Southern Pacific Lines, Houston, Texas.

WRIGHT, MAURICE McGILL, Engr., Christchurch Tramway Board, Christchurch, N. Z.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before January 31, 1929.

Atkinson, A. B., Houston Lighting & Power Co., Houston, Texas

Bayles, E. L., Northwestern Public Service Co., Huron, S. D.

Bennett, L. S., Simplex Wire & Cable Co., Cambridge, Mass.

Bingham, L. A., Mass. Institute of Technology, Cambridge, Mass.

Birkett, C. M., Canadian School of Electricity, Montreal, Que., Can.

Bissett, E., San Antonio Public Service Co., San Antonio, Tex.

Bohlke, W. H., Radio Corp. of America, Brooklyn, N. Y.

Boothby, C. R., Westinghouse Elec. & Mfg. Co., Springfield, Mass.

Brandt, C. A., Northern States Power Co., St. Paul, Minn.

Bronaugh, J., E. L. Phillips & Co., New York, N. Y.

Bronold, A. J., Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.

Brotherson, J. V., Mutual Tel. Co., Erie, Pa.

Bryan, H. H., Can. Westinghouse Co., Hamilton, Ont., Can.

Burger, J., Truscon Steel Co., Youngstown, Ohio

Burkhart, R. F., United Gas Improvement Co., Philadelphia, Pa.

Burns, L. H., Bell Tel. Laboratories, New York, N. Y.

Busher, R. M., Kansas City Pr. & Lt. Co., Kansas City, Mo.

Carter, L. L., Purdue University, West Lafayette, Ind.

Chapman, A. B., Radio Corp. of America, New York, N. Y.

Chapman, H. H., Texas Power & Light Co., Trinidad, Tex.

Charbonneau, L. H., Charbonneau Technical Laboratory, Orange, Calif.
(Applicant for re-election.)

Chidester, J. T., Monongahela West Penn Public Service Co., Fairmont, West Va.

Chisholm, C. F., 4704 Woolworth Bldg., New York, N. Y.

Clarke, G. W. R., Saskatchewan Gov't. Telephones, Regina, Sask., Can.

Clement, W. F., Can. Crocker Wheeler Co., Ltd., St. Catharines, Ont., Can.

Coleman, J. A., Crocker Wheeler Mfg. Co., Houston, Texas

Collins, G. A., San Joaquin Lt. & Pr. Corp., Fresno, Calif.

Connell, D. J., Scranton Electric Co., Scranton, Pa.

Conover, L. J., Lafayette College, Easton, Pa.

Corbin, F. L., 14 Marion St., Brookline, Mass.

Cross, D. M., Canadian & General Finance Co., Ltd., Toronto, Ont., Can.

Cutts, R., Jr., General Electric Co., West Lynn, Mass.

Davy, M. P., Westinghouse Elec. & Mfg. Co., Emeryville, Calif.

De Neutte, E., Western Electric Co., Kearny, N. J.

Depmore, H. G., Southwestern Bell Tel. Co., San Antonio, Texas

Dickey, J. R., Texas Power & Light Co. & Affiliated Companies, Big Spring, Tex.

Diwan, J. N., General Electric Co., Lynn, Mass.

Donnels, A. T., Hartford Steam Boiler Insurance Co., San Francisco, Calif.

Dow, W. G., Aluminum Co. of America, Boston, Mass.

Dytrt, L. F., Iowa State College, Ames, Iowa

Edelstein, H. E., United Elec. Lt. & Pr. Co., New York, N. Y.

Edgar, R. F., University of Minnesota, Minneapolis, Minn.

Egan, F. X., Byllesby Engineering & Management Corp., Chicago, Ill.

Etter, H. L., Saskatchewan Gov't. Telephones, Regina, Sask., Can.

Ewald, F. J., Jr., Kellogg Switchboard & Supply Co., Chicago, Ill.

Ficklen, J. B., Travelers Insurance Co., Hartford, Conn.

Fischer, L. E., (Fellow), North American Lt. & Pr. Co., Chicago, Ill.

Gaynor, J. F. N , G. N. Railroad, Skykomish, Wash.
Ghous, S. G., General Electric Co., Schenectady, N. Y.
Glenn, B., Southwestern Bell Tel. Co., Cushing, Okla.
Glutting, W. A., Safety Cable Co., Bayonne, N. J.
Graham, J. J., 25 Brookfield St., White Plains, N. Y.
Greenberg, E. E., B. A. Wesche Electric Co., Cincinnati, Ohio
Haley, R. T., Globar Corp., Niagara Falls, N. Y.
Hammond, W. M., Home Gas & Elec. Co., Greeley, Colo.
Hampton, W. O., Delta Star Electric Co., Chicago, Ill.
Hanson, W. I., Firestone Steel Products Co., Akron, Ohio
Harter, G. F., The Standard Electric Time Co., Springfield, Mass.
Hauser, G. L., Pennsylvania Water & Power Co., Baltimore, Md.
Headley, F. L., General Electric Co., Philadelphia, Pa.
Hendrickson, D., East Bay Municipal Utility District, Oakland, Calif.
Henshaw, E. N., Southern Pacific Bldg. Co., Houston, Tex.
Hermon, R., Southwestern Bell Tel. Co., St. Louis, Mo.
Herrnfeld, F. P., California Radio Service, Los Angeles, Calif.
Hess, K. F., Consumers Power Co., Grand Rapids, Mich.
Hudson, H. M., H. B. Squires Co., Seattle, Wash.
Hummel, R. C., West Coast Telephone Co., Everett, Wash.
Immer, W. L., General Electric Co., Schenectady, N. Y
Irish, C. E., Wilson-Mauelen Co., Inc., New York, N. Y.
Jarrett, M. G., Bell Tel. Co. of Penna., Pittsburgh, Pa.
Kemp, R. E., International Business Machines Corp., Dayton, Ohio
Kessler, E. S., Pacific Elec. Mfg. Corp., San Francisco, Calif.
Kingsbury, C. R., Ohio Insulator Co., Barberton, Ohio
Kohler, J. H., Howell Electric Motors Co., Howell, Mich.
Kramer, A. W.. Jr., General Electric Co., Schenectady, N. Y.
Kratosky, F. F., Ft. Dodge Gas & Elec. Co., Ft. Dodge, Ia.
Kres, A. J., Duquesne Light Co., Pittsburgh, Pa.
Kunst, F., Can. General Electric Co., Peterboro, Ont., Can.
Larson, H. E., Los Angeles County Road Dept., Los Angeles, Calif.
Liacos, S. J., Munke Jack Co., New York, N. Y.
Lightfoot, T. C., General Electric Co., Philadelphia, Pa.
Lissner, E. D., Public Service Elec. & Gas Co., Newark, N. J.
Lome, J. B., Chicago-Jefferson Fuse & Electric Co., Chicago, Ill.
Lovette, F. D., Alabama Power Co., Birmingham, Ala.
Lund, W. E., Mountain States Tel. & Tel. Co., Great Falls, Mont.
Maeshner, E. A., Frank Rieber, Inc., San Francisco, Calif.
Mangold, H. J., Jr., H. M. Byllesby Co., Pittsburgh, Pa.
Marples, R., United Elec. Lt. & Pr. Co., New York, N. Y.
Mawson, T. H., Alabama Power Co., Birmingham, Ala.
McClure, L. W., Northern Electric Co., Pt. St. Charles, Que., Can.
McCormick, C. G., Bell Tel. Laboratories, Inc., New York, N. Y.
Meahl, H. R., General Electric Co., Schenectady, N. Y.
Miller, H. L., Houston Lighting & Power Co., Houston, Tex.
Miller, J. B., 615 Main St., Oregon City, Ore.
Minnick, O. P., Southwestern Bell Tel. Co., Kansas City, Mo.
Minter, H. J. D., Northern Electric Co., Montreal, Que., Can.
Moak, F. C., New York Edison Co., New York, N. Y.
Moat, D. E., Leeds & Northrup Co., Philadelphia, Pa.
Morris, E. W., Westinghouse Elec. & Mfg. Co., Los Angeles, Calif.
Mueller, M. M., Montana Power Co., Columbus, Mont.
Mulvaney, W. H., So. Calif. Edison Co., La Canada, Calif.
Nevins, G. W., Whiffen Elec. Co., White Plains, N. Y.
Norcross, A. S., Mass Institute of Technology, Cambridge, Mass.
Nuhfer, W. L., Appalachian Electric Power Co., Cabin Creek, W. Va.
Pardee, A., Detroit Edison Co., Detroit, Mich.
Perry, M. L., Jr., Kansas Pr. & Lt. Co., Topeka, Kans.
Perry, W. J., United Elec. Lt. & Pr. Co., New York, N. Y.
Pless, G. R., Mexican Tel. & Tel. Co., Mexico, D. F., Mexico
Popper, J. T., Hentshel Muller & Co., Ltd., Montreal, Que., Can.
Prehn, V. N., Public Service Elec. & Gas Co., Irvington, N. J.
Rei, H. D., Sr., Crouse-Hinds Co., Cincinnati, Ohio
Rend, R. R., Montana Power Co., Butte, Mont.
Rex, E. C., University of Washington, Seattle, Wash.
Rich, M., Carleton-Mace Engg. Corp., Boston, Mass.
Rights, H. T., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Robinson, P. H., Houston Lighting & Power Co., Houston, Texas
Rochells, J. J., Illinois Bell Tel. Co., Chicago, Ill.
Rockwell, R. B., National Elec. Lt. Ass'n., New York, N. Y.
Roman, W. G., Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa.
Ross, R. H., Bell Tel. Laboratories, New York, N. Y.
Rubinstein, H. W., Globe Electric Co., Milwaukee, Wis.
Ruiz, J. J., 24 Nott Terrace, Schenectady, N. Y.
Ryan, A. R., General Electric Co., Pittsfield, Mass.
Sax, E. J., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Schetz, A. J., Electric Bond & Share Co., New York, N. Y.
Schiffmayer, G. F., Public Service Elec. & Gas Co., Newark, N. J.
Schilling, E. W., Iowa State College, Ames, Ia. (Applicant for re-election.)
Schissler, C. E., Bell Tel. Laboratories, New York, N. Y.
Schneemann, J., Victor X-ray Corp., Chicago, Ill.
Schwarz, H. F., General Electric Co., Schenectady, N. Y.
Seaman, J. L., Union Gas & Elec. Co., Cincinnati, Ohio
Setter, J. A., General Electric Co., Schenectady, N. Y.
Sheridan, R. J., Michigan Bell Tel. Co., Detroit, Mich.
Sherwood, W. E., United States Patent Office, Washington, D. C.
Shiland, J. E., Cleveland Electric Illuminating Co., Painesville, Ohio
Silver, R. C., McGill University, Montreal, Que., Can.
Skinner, T. V. S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Smith, H. W., Southern Sierras Power Co., Riverside, Calif.
Smith, U. D., State Trade School, Torrington, Conn.
Smith, W. P., Driver-Harris Co., Morristown, N. J.
Sonon, A. H., Pennsylvania Water & Power Co., Baltimore, Md.
Spatz, N. S., Public Service Elec. & Gas Co., Newark, N. J.
Spaulding, A. M., Mountain States Tel. & Tel. Co., Denver, Colo.
Spellman, C. C., Electric Bond & Share Co., New York, N. Y.
Staller, A. W., Crescent Insulated Wire & Cable Co., Trenton, N. J.
Steeves, C. M., Canadian & General Finance Co., Ltd., Toronto, Ont., Can.
Sullivan, G. L., University of Santa Clara, Santa Clara, Calif.
Svensson, G., American Rotor Corp., Portland, Ore.
Swain, R. R., General Motors Research Corp., Detroit, Mich.
Taylor, E. L., Norton Co., Worcester, Mass.
Tebo, J. D., Bell Tel. Laboratories, New York, N. Y.
Toepperwein, G. A., Electrical Research Products, Inc., Dallas, Tex.
Troitsky, S. P., Westinghouse Elec. & Mfg. Co., Rockport, Wash.
Trost, F. J., Public Service Elec. & Gas Co., Newark, N. J.
Tyler, E. L., National Broadcasting Co., New York, N. Y.
Uzunoff, N., 366 Madison Ave., New York, N. Y.
Van Kirk, C. A., Pacific Tel. & Tel. Co., Berkeley, Calif.
Vasauskas, S., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Vivell, A. E , Johns Hopkins University, Baltimore, Md.
Wahlqvist, P. B., (Member), Empresa de Telefonos, Ericsson, S. A., Mexico, D. F., Mex.
Walback, R. D., Allen & Billmyre Co., New York, N. Y.
Warrington, P. E., U. S. Army, Riverside, Calif.
Weller, R., Mechanics Institute, Rochester, N. Y.
Wharton, H. A., Public Service Gas & Elec. Co., Newark, N. J.
Wilcox, S. H., Public Service Elec. & Gas Co., Trenton, N. J.
Willis, J. D., Canadian General Electric Co., Peterboro, Ont., Can.
Winkfield, H. S., (Member), Northeastern University, Boston, Mass.
Winstandley, M. S., Louisville Gas & Elec. Co., Louisville, Ky.
Wood, A. B., University of Tennessee, Knoxville, Tenn.
Worel, F , Michigan Bell Tel. Co., Detroit, Mich.
Wright, R. F., Bristol Co., Waterbury, Conn.
Young, F. W., Electrical Engineers Equipment Co., Melrose Park, Ill.
Zehner, R. W., Elliott Co., Ridgway, Pa.
Zuch, H. W., The Electrical Service Co., Austin, Tex.

Total 174.

Foreign

Adolph, J., (Fellow), Berliner Stadtische Elektrizitatswerke Akt-Ges., Berlin, Germany
Golden, R. E., The General Electric Co., S. A., Buenos Aires, Argentina
Matsuoka, H., Nippon Electric Power Co., Ltd., Osaka, Japan
Parr, W., Shanghai Municipal Electricity Dept., Shanghai, China
Ramanathan, R., Madras Electric Supply Corp., Ltd., Vepery, Madras, India
Robertson, A. T., (Member), Messrs. J. H. Holmes & Co., Ltd., Newcastle-on-Tyne, Eng.
Smith, R. G., Shanghai Mutual Tel. Co., Shanghai, China
Warren, H., Municipal Electrical Dept., Shanghai, China
Wiewell, M., University of Porto Rico, Mayaguez, Porto Rico

Total 9.

STUDENTS ENROLLED

Acheson, Robert E., University of Missouri
Andrews, Charles M., Jr., Virginia Polytechnic Institute
Bahr, Paul Albert, Lehigh University
Baine, Clyde D., Mississippi A. & M. College
Banks, John F., Mississippi A. & M. College
Barlow, Jack M., Georgia School of Technology
Batchelder, Charles F., Northeastern University
Baum, Willard U., Drexel Institute
Bauman, Carl L., University of South Dakota
Baxter, W. A., University of North Carolina
Berig, Leon, Northeastern University
Blair, Howard A., University of Cincinnati
Bower, George H., Stevens Institute of Tech.
Bowers, George R., Drexel Institute
Breitwieser, Charles J., Univ. of North Dakota
Bridges, John J., Jr., Louisiana State University
Brock, Frederick, Ohio University
Brooks, Cuyler W., Georgia School of Technology
Brotzman, E. S., Lehigh University
Brouse, Harold L., Case School of Applied Science
Brugh, Goben E., Virginia Polytechnic Institute
Burnett, Henry J., Rhode Island State College
Burnett, William C., University of North Carolina
Burroughs, Arthur, Harvard University
Calilan, Casimiro, Lewis Institute
Caparone, Mike J., Pennsylvania State College
Chapman, William R., University of Virginia
Charrier, George M., University of North Dakota
Cockrem, Thomas F., Case School of Applied Science
Conron, William H., New York University
Cowles, Henry R., Case School of Applied Science
Coy, Clifford D., University of Cincinnati
Cummings, Howard F., University of Colorado
Danko, Joseph T., Lehigh University
Dennis, James K., Newark College of Engineering
Diehl, Stanley C., Lehigh University
Di Iorio, Frank, Brooklyn Polytechnic Institute
Di Julio, Fiore, Lewis Institute
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Florance, Robert D., University of North Dakota
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Gallup, Royal K., Worcester Polytechnic Institute
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Glover, Ralph P., University of Cincinnati
Gould, Wendell, State College of Washington
Grabensteder, Louis, University of Cincinnati
Grate, Howard W., University of Cincinnati
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Gross, Ernest T., Jr., University of North Carolina
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Hannon, Millard W., Mississippi A. & M. College
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Haskell, David C., Swarthmore College
Hayes, Charles P., Jr., Univ. of North Carolina
Hazell, William, Jr., Newark College of Engg.
Heckman, R M., Drexel Institute
Herman, Lester C., Lehigh University
Hills, Wesley E., Northeastern University
Hines, Henry J. Jr., University of North Carolina
Holt, Joseph W., Jr., University of North Carolina
Hooper, Charles K., University of Maine
Hoover, William D., Columbia University
Horslin Carroll E., University of Maine
Hortenstine, Albert W., University of Cincinnati
Hunter, William I., Clemson Agricultural College
Huss, Paul O., University of Michigan
Jaffe, Jacob J., Worcester Polytechnic Institute
Jeffries, Joseph. Jr., Lehigh University
Johnson, Charles S., Northeastern University
Johnson, Robert R. Engineering School of Milwaukee
Jones, William C , Northeastern University
Keithley, Frank E., Engg. School of Milwaukee
Kellers, Frank Jr., Clemson Agricultural College
Kennedy Robert H., University of South Carolina
King Charles P. J., Lehigh University
Klenk, Lorenz M., Newark College of Engineering
Kucera, John H., Virginia Polytechnic Institute
Kuntz, Stephen A., Lehigh University
Lauper, Max M., Georgia School of Technology
Lawton, Charles DeW., University of Michigan
Littlefield, Raymond W., Northeastern University
MacGregor, Charles W., University of Michigan
Malin, Clifford T., Engg. School of Milwaukee
Martin, Jack E., Georgia School of Technology
Massow, George, Detroit Institute of Technology
Matson, Uno A., Worcester Polytechnic Institute
McConnell, Robert C., Univ. of North Dakota
McKechnie, John S., University of North Dakota
McLeary, Andrew G., University of Tennessee
Meagher, Joseph J., New York University
Middleton, J. Edward, University of Cincinnati
Miller, Arthur F., University of North Dakota
Miller, Carl E., University of Cincinnati
Mills, Francis L., Detroit Institute of Technology
Mitchel, Ralph H., University of Michigan
Morris, Henry D., University of Cincinnati
Mooshian, John L., Worcester Polytech. Institute
Mosley, Earl A , University of Colorado
Moseley, Sam L., Texas A. & M. College
Moyers, Eugene E., University of Tennessee
Nesslage, Charles F., Princeton University
O'Callaghan, Jerome J., University of Cincinnati
Olsen, Oscar F., Georgia School of Technology
Olsen, Ronald W., University of North Dakota
Olson, Elmer L., Universityof Missouri
Oman, Nils J., Worcester Polytechnic Institute
Parrott, William G., Jr., Clemson Agricultural College
Pavely, Wilfred T., University of Cincinnati
Paxson, Ronald E., University of Michigan
Payne, Frank C., University of Missouri
Pierce, Brister B., Louisiana State University
Pierce, Floyd P., Ohio University
Potter, Frank G., Lehigh University
Preacher, Gerald H., University of South Carolina
Quarles, Gilford G., University of Virginia
Reed, Joe F., University of Cincinnati
Reuter, Herman H., Cooper Union
Richey, Charles E., Georgia School of Technology
Rinke, James F., University of Louisville
Roane, John P., Virginia Polytechnic Institute
Roberts, Edwin R., Lehigh University
Roberts, Walter F., Virginia Polytechnic Institute
Robinson, Harris A., University of Pennsylvania
Roddy, Vincent S., Case School of Applied Science
Rose, Wellon T., Clemson Agricultural College
Rosebrook, Homer, Ohio Northern University
Samulionis, John, Lewis Institute
Schifino, Anthony G., Ohio Northern University
Schmidt, Paul C., Worcester Polytechnic Institute
Schroeder, Harold H., Akron University
Schwerer, Fred C., Jr., Pennsylvania State College
Shallenberger, Onslow P., University of Colorado
Sharp, William B., University of North Carolina
Shelton, Benjamin, University of South Carolina
Shepard, Robert E., Virginia Polytechnic Institute
Sherarts, Theodore W., Univ. of North Dakota
Silverberg, Lawrence B. O., Worcester Polytechnic Institute
Singer, H. F , Lehigh University
Skinner, Charles H , Engg. School of Milwaukee
Smith, Frederic N., Case School of Applied Science
Snedeker, Marion L., Ohio Northern University
Squire, Edmund M., New York University
Standring, Henry A., University of Colorado
Starrett, Randall McK., Univ. of North Carolina
Steuart, George B , University of Colorado
Stickelberger, Louis R., Univ. of North Dakota
Strawn, Thomas F., Lehigh University
Strohl, Wellington M., University of Washington
Sylvester, Robert A., Lehigh University
Szabo, William F., Case School of Applied Science
Talley, George W., Missouri School of Mines
Thomas, Marvin I., University of Illinois
Tiedeman, Edward, University of North Dakota
Torbit, James G., Mass. Institute of Technology
Trapp, Henry J., University of Cincinnati
Turner, Charles A., Massachusetts Institute of Technology
Van Bussum, Walter C., Ohio University
Volland, Leonard L., Case School of Applied Science
Vroom, William H., Lehigh University
Walkonen, Taito K., Worcester Poly. Institute
Walters, Marvin R., University of Virginia
Walters, Vernon O., University of Colorado
Weisbaum, Ira, New York University
Weiss, Edward H., Lehigh University
Welborn, J. D., Clemson Agricultural College
West, Virgil, University of North Dakota
Wickersham, Wilfred H., Haverford College
Williams, David C., University of Tennessee
Willke, Herbert L., A. & M. College of Texas
Wilson, Maurice A., University of Michigan
Wilson, Wendall O., Akron University
Winchell, Walter H., Northeastern University
Witt, Morris, Georgia School of Technology
Woodward, John D., Lehigh University
Wortman, William J., Univ. of North Carolina
Zelenka, Louis G., Louisiana State University
Ziegler, Melvin F., Ohio University
Total 190

Officers of the A. I. E. E., 1928-1929

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(Term expires July 31, 1929)
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(Term expires July 31, 1930) BANCROFT GHERARDI

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(Terms expire July 31, 1930)
E. B. MERRIAM (District No. 1)
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*T. Commerford Martin, 1887-8.
Edward Weston, 1888-9.
Elihu Thomson, 1889-90.
*William A. Anthony, 1890-91.
*Alexander Graham Bell, 1891-2.
Frank Julian Sprague, 1892-3.
*Edwin J. Houston, 1893-4-5.
*Louis Duncan, 1895-6-7.
*Francis Bacon Crocker, 1897-8.
A. E. Kennelly, 1898-1900.
*Carl Hering, 1900-1.
*Charles P. Steinmetz, 1901-2.
Charles F. Scott, 1902-3.
Bion J. Arnold, 1903-4.
John W. Lieb, 1904-5.
*Schuyler Skaats Wheeler, 1905-6.
*Samuel Sheldon, 1906-7.
*Henry G. Stott, 1907-8.
Louis A. Ferguson, 1908-9.
Lewis B. Stillwell, 1909-10.
Dugald C. Jackson, 1910-11.
Gano Dunn, 1911-12.
Ralph D. Mershon, 1912-13.
C. O. Mailloux, 1913-14.
Paul M. Lincoln, 1914-15.
John J. Carty, 1915-16.
H. W. Buck, 1916-17.
E. W. Rice, Jr., 1917-18.
Comfort A. Adams, 1918-19.
Calvert Townley, 1919-20.
A. W. Berresford, 1920-21.
William McClellan, 1921-22.
Frank B. Jewett, 1922-23.
Harris J. Ryan, 1923-4.
Farley Osgood, 1924-25.
M. I. Pupin, 1925-26.
C. C. Chesney, 1926-27.
Bancroft Gherardi, 1927-28.

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Frederick M. Servos, Rio de Janeiro Tramways Lt. & Pr. Co., Rio de Janeiro, Brazil, S. A.
Charles le Maistre, 28 Victoria St., London, S. W. 1, England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E., France.
F. W. Willis, Tata Power Companies, Bombay House, Bombay, India.
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
P. H. Powell, Canterbury College, Christchurch, New Zealand.
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

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(Terms expire July 31, 1930)
George Gibbs, Samuel Insull, Chairman, Ralph D. Mershon.
(Terms expire July 31, 1931)
John W. Howell, L. F. Morehouse, David B. Rushmore.
(Terms expire July 31, 1932)
E. B. Craft, Paul M. Lincoln, C. E. Skinner.
(Terms expire July 31, 1933)
Charles F. Brush, D. C. Jackson, Elmer A. Sperry.

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Power Factor Correction.—Bulletin, 48 pp., "Reducing the Cost of Electric Power." Deals with the subject of power factor correction with capacitors (static condensers). Electric Machinery Manufacturing Company, 14th & N. E. Tyler St., Minneapolis, Minn.

Oil Circuit Breakers.—Bulletin C-1803, 8 pp. Describes new Westinghouse type O-331 circuit breaker for indoor and outdoor service in capacities of 600, 1200 and 2000 amperes, 25,000 volts. Westinghouse Electric & Manufacturing Company, East Pittsburgh, Penn.

Outdoor Substations.—Special Publication 57. Describes a radically new type of high-voltage, outdoor substation, with rotating busses which also function as switch-operating mechanisms. An outstanding feature of the station is that all heretofore idle insulators, connections and joints have been eliminated, resulting in a marked reduction in the number of insulators heretofore necessary. Delta-Star Electric Company, 2400 Block Fulton Street, Chicago, Ill.

Transformers.—Bulletin 160, 52 pp. Describes Wagner distribution transformers in single-phase and three-phase, pole-type and subway-type, in ratings up to and including 500 kva. One-half of the catalog is devoted to a detailed description of the design and construction of Wagner distribution transformers and the remainder of the catalog is devoted to ratings, shipping weights, prices, etc. Wagner Electric Corporation, 6400 Plymouth Avenue, St. Louis, Mo.

NOTES OF THE INDUSTRY

The Ohio Brass Company, Mansfield, O., announces the appointment of Harvey H. Hoxie as district sales manager, Power Utilities Division, for the New England territory, with offices in the Little Building, 80 Boylston Street, Boston, Mass.

The James R. Kearney Corporation, St. Louis, announces that through the past support and patronage of its products, it is able to announce a new line of equipment, called Kearney Hot Line Tools and Accessories. These tools eliminate the hazards of live line maintenance. They are made in the U. S. A. by Tip's Tool Company, Incorporated patent rights.

The Synthane Corporation, incorporated in September 1928 is completing the building of its plant at Oaks, near Philadelphia, and expects to commence production of laminated Bakelite products in the early Spring. R. R. Titus, formerly Vice-President and General Manager of the Diamond State Fibre Company and the Celoron Company of Bridgeport, Pa., heads the corporation as President, with J. B. Rittenhouse as Vice-president and George J. Lincoln, Secretary and Treasurer.

Wagner Electric Corporation, St. Louis, has appointed R. L. Matthews to the sales force of its Chicago branch ffice. Mr. Matthews has previously been active in the electrical field, being connected with such organizations as the Michigan Bell Telephone Company, the Armstrong Cork & Insulation Company and the National Electric Products Corporation. N. H. Spencer has been added to the Dallas, Texas, sales force. Mr. Spencer has held several managerial posts with power companies. His last position was with the Pittsburgh Transformer Company, with whom he was connected for the past eight years.

Gerard Swope on the Business Outlook for 1929.—The following statement has been issued by Gerard Swope, President of the General Electric Company. "The electrical manufacturing business for 1928, on the whole, has been quite satisfactory, with an increase in volume of about seven per cent. It is remarkable that the use of electric current in the homes and in the factories continues its high rate of increase from year to year. The 1928 rate of increase is about eight per cent and, as stated last year, this is becoming one of the best indices of general and industrial conditions in America. Basic economic conditions are sound, inventories not unduly expanded, credits and collections satisfactory, earnings of labor are high, and employment steady, all of which presage a favorable outlook for 1929."

A New Conduit.—A new kind of conduit has been announced by the Electrical Division of Steel and Tubes, Inc., Cleveland, Ohio, a subsidiary of the Republic Iron & Steel Company. This new product is known under the 1928 National Electrical Code as "electrical metallic tubing."

Steeltubes Electrical Metallic Tubing is a thin wall, rigid conduit having all of the characteristics of the so-called heavy, standard conduit but with a lighter wall. Its use as a rigid conduit has been sanctioned by Section 508 (new) of the 1928 National Electrical Code. It will bear the underwriters' label. The wall of this new conduit is approximately one-third the thickness of standard conduit. It is used without threading, connections being made by means of a union compression type coupling. Part of this coupling may be used as an adapter to connect the conduit to any standard threaded or threadless fitting.

Largest Boilers for East River Station. The New York Edison Company and the companies associated with it in supplying electric service in metropolitan New York, have closed a contract with the International Combustion Engineering Company for three boilers that will be the largest ever built. They are to be installed in the East River Generating Station of The New York Edison Company and will supply steam to drive the largest single-shaft, single-unit electric generating machine in the world, a 160,000 kilowatt turbo-generator, now being constructed by the General Electric Company.

The over-all height of the boilers, which are of the Double Ladd type with fin tube water walls, will be 95 feet, with furnaces 23 feet wide and extending back 65 feet. Each will supply a maximum of 800,000 pounds of steam per hour at a temperature of 700 degrees fahrenheit at 425 pounds per square inch pressure. Delivery of the boilers is expected to start in about four months, and the unit will be placed in operation about September 1, 1929.

Richard M. Kerschner, associated with Hubbard & Company for the past sixteen years, succumbed to a heart attack on December 8, 1928, at his home in Zelinople, Pa. Mr. Kerschner joined the sales department of Hubbard & Company in 1914, later becoming sales manager. In 1924 he supervised the building of the New Hubbard factory at Oakland, Cal., remaining in charge there until 1927 when he returned to Pittsburgh to assume charge of the Department of Development and Research in which position he was active up to the time of his death. He had built up a host of friends throughout the central station men of the country.